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Journal of Sedimentary Petrology

A Publication of the Society of Economic Paleontologists and Mineralogists
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Journal of Sedimentary Petrology

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NOTICE

Articles submitted for publication to the JOURNAL OF SEDIMENTARY PETROLOGY should have a prefatory abstract and sufficient postage should be sent by the author to prepay the return of the manuscript as it has been found that many articles require more or less revision before publication.

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JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 5, NO. 1, PP. 3–8, FIGS. 1–2, TABLES I–II,
APRIL, 1935

SOME SUGGESTIONS FOR HEAVY MINERAL INVESTIGATIONS OF SEDIMENTS

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California Institute of Technology, Pasadena, California

ABSTRACT

Attention is directed to the variability in quantitative relations between heavy minerals as a consequence of changes in the texture of sediments. It is suggested that for quantitative comparisons of heavy minerals, materials of the same grade-size should be utilized.

Various methods in use for describing quantitative relations between heavy minerals are critically analysed. A new method of representation is suggested. A standard or type sample is selected. It is screened and the heavy minerals are separated from the suitable grade-size fractions. A known portion of the heavy mineral crop is counted and the abundance of each mineral species is established for a definite weight of uniformly sized material. The abundance of any mineral species in other samples is then given by a comparison with this standard.

PART I

In the course of a petrological study of certain sediments it was found more suitable to mount heavy mineral grains of approximately uniform size rather than an ungraded aggregate of minerals. This raised the question as to whether the quantitative relations peculiar to a sediment could be observed better by examining and comparing heavy minerals of the same same size rather than by making use of crops which had been secured from unscreened samples. Both schemes have been employed by investigators of sediments. A study of the problem has convinced the writer that results secured by the use of one of these methods can not be duplicated by the other except under very favorable circumstances. A review of the literature, prior to the writing of this paper, failed to disclose any definite statement regarding the superiority of either method. In a recent paper, however, it is to be noted that Lincoln Dryden (1) decries the practice of making comparisons between heavy minerals of differing grade size.

Over a limited area, there may exist between the mineral constituents of any one formation a distinctive quantitative relationship. This observation is supported by many successful correlations that have been made on the basis of mineral percentages. From a consideration of various data the writer has been convinced that quantitative comparisons made between heavy minerals which have been secured from unscreened sands may often be misleading and that sometimes similarities between samples may be obscured by apparently inexplicable differences in their mineral proportions. This conclusion was reached after the relationship between textural variation of a sediment and the change in percentage

composition of minerals with grade-size was recognized.

Sediments are known to change in texture even over relatively short distances, currents being one of the most vigorous among the numerous agents which produce such changes (2). In the case of some beach sands the textural variation may be considerable (3) and even for marine sediments a variance in texture is commonly observed (4). Coupled with this variable is the significant fact that percentages of heavy minerals are usually different in each of the grade-sizes of a sediment. This is well illustrated by the work of Hawkes and Smythe (5). See figure 1.

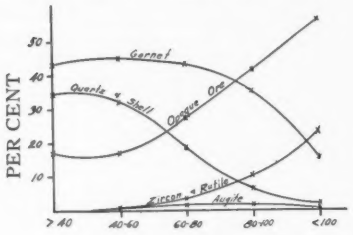

FIG. 1. Illustrating variations in mineral proportions with grain size. From Hawkes and Smythe (5).

With these two facts in mind, viz., variations in texture and variation in the mineral proportions for the different grades, it becomes evident that quantitative comparisons of constituents, if they are to have any significance, should be made only between materials of like size. An inspection of table 1 shows the extreme variation that sometimes occurs in the ratio between the same two minerals in slightly different grades. For the size between one-eighth and one-sixteenth mm., hornblende bears the ratio to magnetite of 84:1, whereas in the portion under one-sixteenth mm. the ratio is 37:40. It is obvious that a sediment with a texture that varied even a small amount in the fraction under one-eighth mm. would show striking variations in its mineral proportions and consequently correlations would be difficult or impossible if comparisons between unscreened materials were made.

TABLE I. *Heavy mineral analysis of glacio-lacustrine sands. From G. A. Thiel* (6)
Per cent by number of grains.

Mineral	Size in mm.			
	$\frac{1}{2}$–$\frac{1}{4}$	$\frac{1}{4}$–$\frac{1}{8}$	$\frac{1}{8}$–$\frac{1}{16}$	$\frac{1}{16}$
Magnetite	—	—	1	40
Hornblende	96	94	84	37
Zircon	1	2	7	6
Tourmaline	—	1	1	—
Titanite	1	—	5	3
Apatite	—	1	2	14
Garnet	1	1	—	—
Biotite	1	1	—	—

It should be remembered that the arguments presented here are applicable only to the problem that relates to quantitative and not to qualitative comparisons of minerals. The writer realizes that probably the greater proportion of correlation work in which heavy minerals are used is done by qualitative means, but it was felt that a knowledge of the precautions necessary for correlating on a quantitative basis should be emphasized.

PART II

Several methods are now in use for describing the petrographic character of sediments. Undoubtedly the simplest of these is the one in which quantitative data are disregarded and the description consists merely

of a list of the minerals that are present. This is sufficient for correlation purposes if each of the formations of a series is characterized by distinctive species of minerals. Yet even at its best it represents a rather incomplete petrographic analysis of a sediment.

A second method in common use, particularly among British investigators of sediments, is the quantitative representation of the mineral constituents by descriptive adjectives or numbers (7).

Of late the tendency has been toward greater accuracy in quantitative description and a scheme in which the mineral constituents of a sediment are represented as percentages of the heavy mineral crop is frequently employed.

It has been recognized by some workers that this method, although more accurate than the two previously described, leaves much to be desired. Invariably the percentage composition of one sample will differ in some degree from a second, even though each has been taken from the same stratum and within a short distance of one another. A higher percentage of a particular mineral in one of the samples is not necessarily an indication of a real increase in the quantity of that mineral. Such an effect may be a consequence of several factors. It might result from a diminution in the quantities of all but that one of the constituents represented, or it might be the consequence of a general decrease in the total crop of heavy minerals with a relatively lesser shrinkage in the amount of the one particular mineral, or it might be caused by a general increase in the crop with a commensurately greater increase for the one constituent. It is evident, therefore, that an increase in the percentage of a mineral may be a consequence of several different combinations of events. Hence, the method of heavy mineral representation which employs percentages that are functions of the total number of heavy grains counted gives an equivocal petrographic description of a sediment.

In an effort to remove some of the defects inherent in the system which has just been described, F. J. Pettijohn (8) proposed a scheme in which the amount of a particularly stable mineral was used as a base from which percentages of the other heavy constituents were calculated; e.g., he arbitrarily chose the amount of garnet present in each sample to represent 100 per cent. This method apparently rests on the premise that minerals which are relatively resistant to abrasion and decomposition occur rather uniformly distributed through a stratum—a proposition that in some instances may be open to doubt. Nevertheless, this method presents an unequivocal petrographic representation of the constituents of a sediment as a function of a particular mineral, although it fails to record general fluctuations of the entire heavy mineral crop when the quantity of the reference mineral varies proportionately as the mass.

A method of recording the actual numerical counts of the heavy constituents of a formation has also been used (9). This scheme is free from the

defects which have been ascribed to the other methods, but similarities between samples are often obscured by general fluctuations of the entire heavy mineral crop.

The writer, therefore, wishes to suggest a plan that is independent of the fluctuations of any minerals within a suite, that records quantitative variations of the entire heavy mineral crop, and that makes similarities between corresponding samples readily apparent. In this method, the first step is to secure a representative mineral analysis of the stratum with which it is desired to correlate. Where the work is not entirely of a subsurface nature, this is accomplished best by collecting several samples from a known outcrop and averaging their results. In detail the work would be as follows: About three samples within a linear limit of 10 feet along the strike of a stratum would be taken. These would then be screened and each sample split into its constituent grade-sizes. The heavy minerals would be separated from the different grades, classified as to species, and counted. A count of all the heavy mineral grains that had been separated from a given grade of sand would not be necessary. By the use of a miniature sample splitter (10), a known fraction of the heavy crop, suitable for counting, could be secured. The grain counts in every case would be reduced mathematically to represent the number of grains in a given weight of graded sand; e.g. 10, 25, or 50 grams. An average of the three samples would be taken as the standard for further comparisons. The average number of grains of each mineral species secured in this fashion would then be assumed to equal 100 per cent for each of the species represented. All future comparisons would be made with the type sample, and the percentages of the various heavy minerals would be functions of the quantities present in the type sample.

The scheme is best made clear by an illustration. Let the sample which will serve as a standard possess in a 20 gram portion of a given grade-size a heavy mineral crop constituted as follows: 150 grains of A, 200 of B, 50 of C, 25 of D, and 100 of E. Let there be four samples which show, respectively, an increase of the entire crop (No. 1 in table 2), a shrinkage of the entire crop (No. 2), little deviation from the reference sample (No. 3), and a strong fluctuation in the quantity of only one mineral species (No. 4).

The table shows that when the proportions between the constituents of a sample are comparable to the proportions which exist in the reference specimen, the effect is to give percentages that are nearly alike for all five components. A general mass increase of the crop produces a percentage ranging over 100 per cent, while a diminution in the crop is indicated by percentages less than 100 per cent. A fluctuation in the quantity of a single component is immediately recognizable by a percentage which differs widely from that of the other constituents.

The proposed scheme lends itself conveniently to graphical representation when the mineral percentages are plotted on a logarithmic scale (see Fig. 2). The norm or reference

sample will always be represented by a horizontal line cutting the ordinate at 100 per cent. Curves of other specimens may lie either above or below the norm but as long as they remain nearly horizontal they suggest a close correspondence to the reference sample. Wide deviations from the horizontal are generally indicative of significant fluctuations in the mineral percentages of the specimen.

In the event that new minerals should appear in some of the samples, it is suggested that they be listed in the table under the head of "Other Minerals" and that their percentages be calculated as functions of an arbitrarily selected base number.

TABLE II.—*Analysis of heavy mineral samples on the basis of a reference sample.*

No. of grains in 20 gms. of — mm. grade size

Sample No.	A	B	C	D	E	Other Minerals	
						F	G
Reference Sample	150	200	50	25	100		
1	305	435	100	55	210		
2	100	140	35	16	66		
3	145	210	50	27	98		
4	155	204	125	28	95		
5	a	b	c	d	e	f	g

Per cent by no. of grains*

	A	B	C	D	E	Other Minerals	
						F	G
Reference Sample	100	100	100	100	100		
1	203	218	200	220	210		
2	67	70	70	64	66		
3	97	105	100	108	98		
4	103	102	250	112	95		
5	$100 \cdot \frac{a}{150}$	$100 \cdot \frac{b}{200}$	$100 \cdot \frac{c}{50}$	$100 \cdot \frac{d}{25}$	$100 \cdot \frac{e}{100}$	$100 \cdot \frac{f}{k}$	$100 \cdot \frac{g}{k}$

* $P = 100 \frac{n}{t}$ where

P = per cent.
n = number of grains of a mineral species in a given amount of a selected grade size of sand
t = number of grains of a mineral species in the same amount of a selected grade size of sand from the reference specimen.
k = any arbitrarily selected constant.

The primary purpose of the method that has been suggested is to furnish a means of description for sediments which is complete, unequivocal, and easily comprehended. It should also be useful where it is desired to correlate with some definitely known formation or stratum.

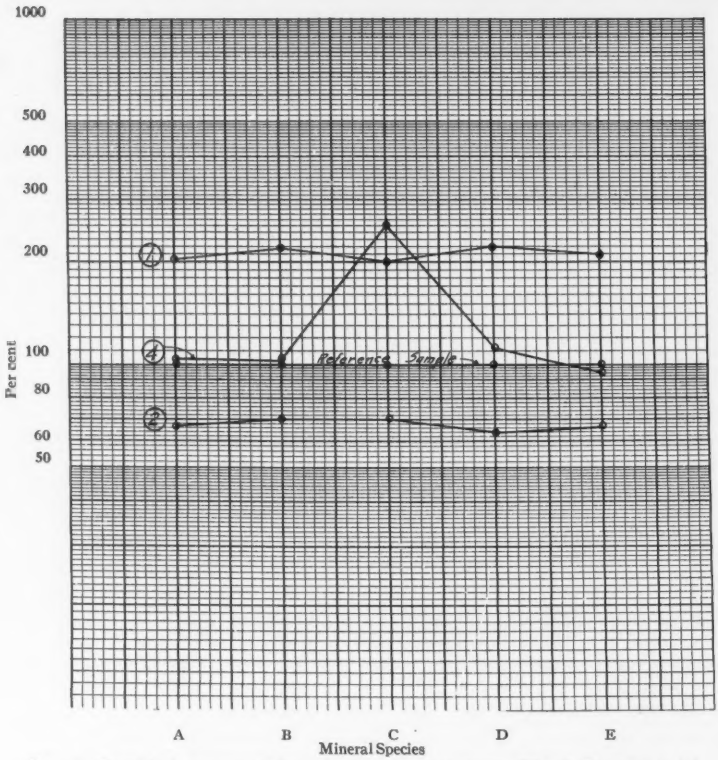

FIG. 2. Graphical representation of mineral percentages. (Note) Curve 3 is left out to avoid confusion of crowded curves.

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JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 5, NO. 1, PP. 9–30, FIGS. 1–5, TABLES I–XVII, APRIL, 1935

A STUDY OF SOME GREAT BASIN LAKE SEDIMENTS OF CALIFORNIA, NEVADA AND OREGON

R. R. SHROCK and A. A. HUNZICKER
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ABSTRACT

Fifty-eight samples of lake sediments from seventeen profiles distributed among twelve playa lakes located in northeastern California, southeastern Oregon and northwestern Nevada were analyzed. The samples were treated with distilled water to find the amount of water-soluble salts; with cold hydrochloric acid (1–1) to determine the amount of acid-soluble matter; and were subjected to elutriation to determine the amounts of sand-silt and silt-clay materials. The water-soluble salts are always of low content (as much as 10 per cent, but rarely over 5 per cent); the acid-soluble matter is variable in amount (20–74 per cent), rarely dropping below 20 per cent; and the sand-silt and silt-clay fractions show great variation from almost pure sands to clays with scarcely any sand in them. Some of the clays are laminated, but the laminations do not appear to represent varves. Crust materials commonly observed on dry lake beds were not found in the sediments.

INTRODUCTION

For a number of years geologists have been interested in using varved sediments as a yard stick for measuring geologic time and as a criterion for interpreting ancient climatic conditions. In a recent discussion of Basin Range lakes, Dr. Isaiah Bowman[1] called attention to another use which might be made of varved and perhaps laminated lake clays as follows:

> Because the lakes of the Great Basin have expanded and contracted in response to climatic change, one naturally turns to that region for a possible correlation between lake history and tree history to see if identical periods of wetness and dryness can be distinguished. Unfortunately, from this standpoint, the lakes of the Great Basin are and have been mostly salt lakes, whereas the banded clays that lend themselves most readily to the dating of events in geological time are formed in fresh-water lakes. A neglected field of study has been the sedimentation process. Until that process is studied in detail and correlated with rainfall, temperature, cloudiness and stream discharge, there is no solid experimental basis for the interpretation of sediments now exposed on basin floors in sections that are accessible. The drought of the past three years has exposed lake floors that have been covered with water for many decades and that have been exposed to view probably not more than once or twice since white occupation of the West. This makes it a matter of urgent importance that the studies of the now dry lake beds should be pushed with all speed before they again become covered with water and the sedimentary record of their fluctuations is again difficult to sample.

During the late summer of 1931, Dr. Ernst Antevs collected samples of lake clays from a number of the Great Basin lakes in northern California and Nevada and in southern Oregon. These were sent to Dr. W. H. Twenhofel, at the suggestion of

[1] Bowman, I., Correlation of sedimentary and climatic records: *Science*, vol. 75, p. 594, 1932.

whom the following study was initiated. The analytical work was carried out in the Sedimentation Laboratory at the University of Wisconsin and was financed by the American Geograpical Society, with whose kind permission the results are here presented. Financial assistance was given Dr. Antevs by the Carnegie Institution through the American Geographical Society.

Objectives of the investigation.—Under date of April 25, 1932, Doctor Antevs wrote to Doctor Twenhofel as follows:

> The samples of the lake sediments were taken because it was thought possible that they recorded changes in precipitation, recorded fluctuations between plenty of water in the lake basins and dry lake bottoms. However, I did not *see* any indication of cycles in the sediments except for probable varves in two profiles. If you can discover any cycles, and their length could be determined, it would be a fine thing. When the lakes dry, a surface crust of one kind or another is formed. Does this crust completely disappear, when the lake is filled up again? I thought there might be some indications of this crust left, but I did not *see* any in the profiles.

With the suggestions of Doctors Bowman and Antevs in mind, the sediments were studied, therefore, to determine (1) whether there was any lamination present, and if that lamination had significance as to climatic conditions, cycles of deposition and length of the time of deposition. (2) Search was made, also, for any evidence of the incorporation of crust material in the sediments. Since the study of the sedimentation processes concerned in the formation and deposition of the Great Basin lake sediments has been somewhat neglected analyses were made in order to learn more about the constitution and characteristics of the sediments: (*a*) Samples were selected from each distinct lithologic unit in each profile and were dried; (*b*) a small portion was then treated with distilled water to determine the water-soluble content; (*c*) after drying this same portion was next treated with cold hydrochloric acid (1–1) to determine the amount of acid-soluble salts present; (*d*) a second portion of the original sample, weighing from 25 to 40 grams was subjected to elutriation and the sand-silt and silt-clay fractions determined.

Location of the Lakes and Their Geographic Relations.—The twelve lakes from which the samples were collected are located in northeastern California, northwestern Nevada and southeastern Oregon (Fig. 1). In all cases these lakes lie in the lowest parts of depressed, flat areas surrounded partly or almost completely by high mountain ranges which rise abruptly from 1,000 to 5,000 feet above the adjacent basins. These ranges are often much steeper on one side than on the other, are composed in most cases of great tilted blocks which have been sculptured into their present configuration since the deformation, and exhibit a general north-south trend, although there are numerous exceptions to this trend where cross-faults complicate the structure and the resultant topography.

The intermontane basins are filled deeply (in one case as much as 800 feet) with sediments which have been

washed and blown into them from the adjacent ranges. Students of the Great Basin ranges have pointed out the important processes and agencies which are and have long been tearing down the uplifted blocks and filling in the depressed areas between. The sediments discussed in the present report are those which have found a temporary resting place in the shal-

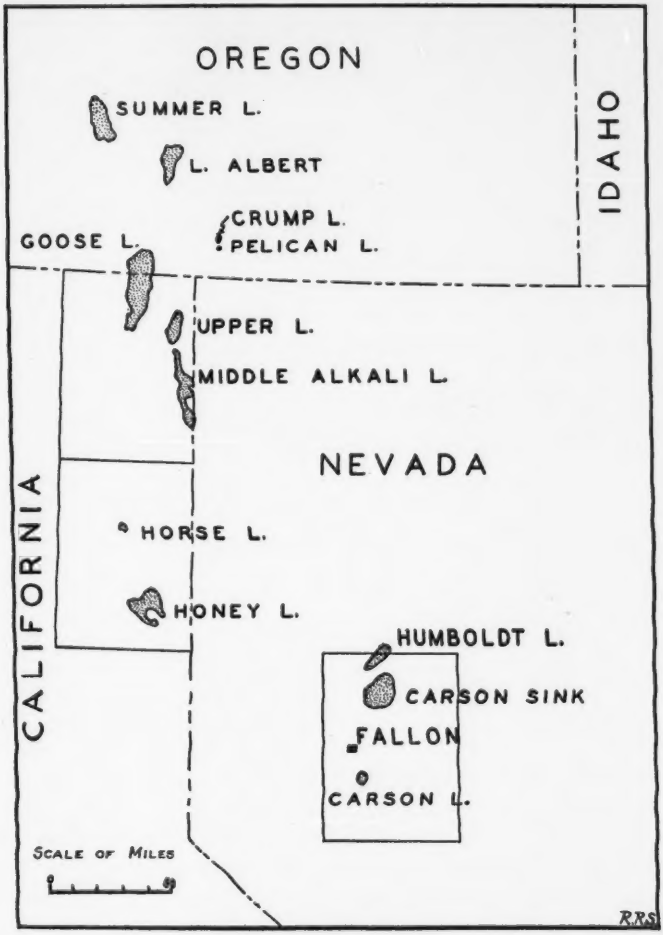

FIG. 1. Index map showing the location of the Great Basin lakes from which sediments were collected.

low lakes occupying the lower sites in these extensive intermontane basins. It is to be expected that the sediments reflect to some extent the environmental conditions under which they were deposited; that they give some indication of the means by which they reached their present position; and that they furnish some clue as to the nature of the source rock in which they had their origin.

Method of Presentation of Data.—The lakes will first be considered by states, and after their general relations have been discussed, they will be treated individually. Since neither of the writers has been in the region from which the sediments were collected, information concerning it must of necessity come from published and unpublished maps and reports. Additional information has been obtained from Doctor Antevs' field notes. These various sources will be acknowledged in the proper place.

THE OREGON LAKES

Summer Lake, Lake Abert, Crump Lake, Pelican Lake and the northern third of Goose Lake lie in Oregon (Fig. 2). In all cases the drainage into these lakes is small and of local origin. Permanent streams are not common and much of the erosion and transportation takes place at times of sudden precipitation. These lakes, according to Waring,[2] were much larger during the Pleistocene than at present, as is indicated by elevated terraces with fresh-water shells, deltaic formations rather than alluvial fans above the present lake levels, and the recorded observations of geologists who have visited the region at various times in the past. In some cases the lakes were over 200 feet deeper than at present. Records show that the lake levels have fluctuated considerably during the past.

All of the lakes are elongated in a general north-south direction and are bordered on one or more sides by steep slopes. A high cliff begins just north of Summer Lake and borders it on the western side, turning to the eastward at the south end of the lake and again to the southward along an extensive marsh at the south end of which it joins a second escarpment which extends in a general north-south direction. The latter begins a considerable distance north of Lake Abert, extends southward along the eastern edge of that lake, joins the escarpment mentioned above and continues on to the southward along the eastern margin of Goose Lake, dividing that lake from several other lakes which lie to the eastward (Fig. 2). The Warner lakes, of which Crump and Pelican lakes are small remnants, lie in a basin bordered along the eastern margin by an escarpment which rises abruptly some 2,500 feet above the lakes. Several of the Oregon lakes are surrounded by extensive marshy areas which would become lake bottoms if the water level were to rise a few tens of feet.

The surficial rock in this part of Oregon consists of two kinds of material—volcanic and alluvial. The

[2] Waring, G. A., Geology and water resources of a portion of south-central Oregon: *U. S. Geol. Survey, Water Supply Paper* 220, pp. 30–43, 1908.

great tilted blocks, of which the upturned edges form the conspicuous escarpments bordering some of the lakes, are composed of volcanic effusives, muds and tuffs, mainly of Miocene age. After the tilting of the blocks the intermontane basins were filled with Pleistocene and Recent alluvial materials washed and swept into them by the various erosive and transporting agencies. Some scattered lacustrine deposits are included in these alluvial deposits, indicating that the level of the lakes was once higher than at present.

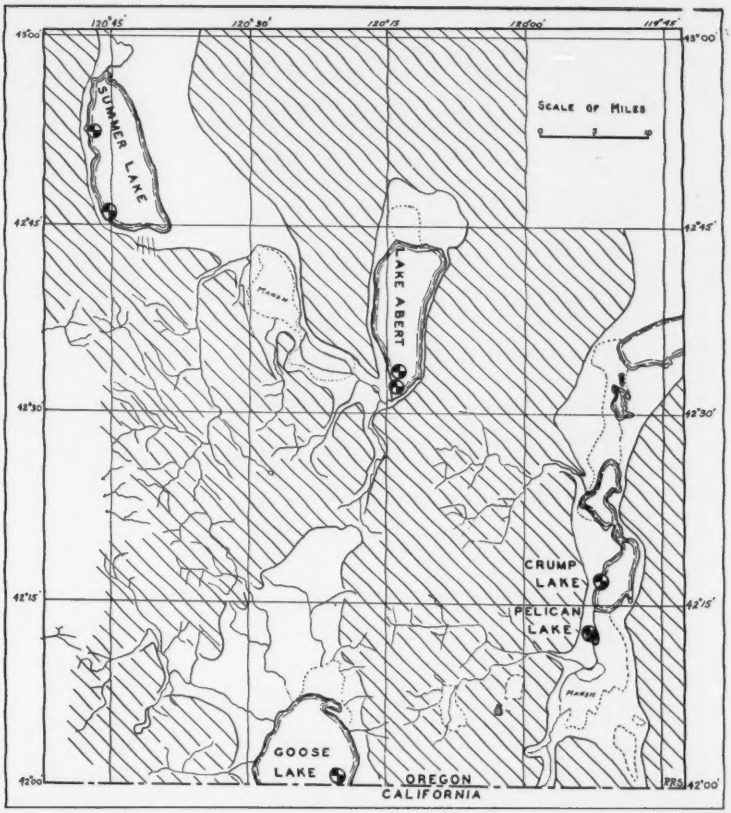

FIG. 2. Map showing the location and distribution of the Oregon lakes from which samples were collected. The location of the profiles is indicated by a partly filled circle. Highlands are indicated by oblique lining. (Outline map after G. A. Waring, *U. S. Geol. Survey, Water Supply Paper* 220, 1908.)

SUMMER LAKE

Summer Lake is bordered along the western and southern sides by a steep escarpment which rises precipitously 2,500 feet above the basin. The drainage from this steep slope flows eastward and northward into the lake. Some drainage also comes from the north. To the north and east the lake is bordered by a low flat plain five or six miles wide which gives way to rougher country eastward (Fig. 2).

Two sets of samples were taken from Summer Lake. Their locations are indicated by the letters A and B on figure 2. The complete data for the samples will be found summarized in tables 1 and 2.[3]

Locality A (Table 1).—At the time the sediments were collected from Summer Lake it was considerably smaller than as shown on Figure 2. The profile, of which the location is indicated by the letter A, extended to a depth of 17 feet, but adequate samples were taken for only the upper 3 feet.

TABLE I. *Data concerning sediments at Locality A, Summer Lake, Oregon*

Location (Antevs).—A—At southwest corner of lake three-fourths of a mile from recent shore. In October, 1931, water along main axis of lake, from 2 to 3 miles off the south shore to the northern end. On the west side water reaches to points 2 or 3 miles from recent shore. No vegetation. Snowy white crust. Foot sinks 1 inch.

Notes on sediments (Antevs).—At surface, 1 to 5 mm. of white granular crust of salt. Section below surface and downward; (1) brown clay, nearly dry, 2 inches; (2) brown, moist clay similar to (1), 8 inches; (3) lead-colored, soapy clay, poorly stratified, 9 feet or more; (4) black sediment at depths of 13 feet and 17 feet.

Notes and sediments (Shrock).—From surface downward: (1) brown clay, nearly dry, 2 inches; (2) lead-colored soapy clay, drying with considerable shrinkage to hard pebble-like chunks. The fracture is smoothly conchoidal. From the material in the troughs the sediment appears homogeneous throughout.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*
Depth below surface in inches	0–7	14–21	30–36
H_2O Soluble	9.1	6.6	4.9
HCl Soluble	24.7	23.5	32.1
Sand-Silt	38.7	45.8	52.3
Silt-Clay	61.3	54.2	47.7

The white granular salt at the surface tastes quite salty but not all of it dissolves in water. When treated with cold hydrochloric acid, however, all of the crust that is not soluble in water completely dissolves in the acid. The water-soluble salts increase as the surface is approached (4.9 per cent to 9.1 per cent). The upper 2 feet show nearly 25 per cent of *calcareous*[4] material, but this figure has increased to 32 per cent at the base of the first 3 feet, and a preliminary test of the underlying 14 feet showed considerable calcareous matter to the base of the boring. The sand-silt fraction increases with depth from 38.7 per cent near the top to 53.2 per cent near the base. There is no lamination evident except for a small band, about one-half inch thick, 1½ feet below the surface. There is like-

[3] In all of the following tables the sources of the various data are acknowledged by placing the author's names in parentheses. In the analytical data Mr. Hunzicker determined the sand-silt and silt-clay fractions; Doctor Shrock determined the soluble materials and described the sediments as they appeared in the troughs and after their various treatments. Doctor Antevs collected the samples and described general conditions in the field, and his notes have been retained here with little or no change. In his field work Doctor Antevs was given financial assistance by the Carnegie Institution, through the American Geographical Society.

[4] The term *calcareous* will be used throughout this report for the salts which dissolved in cold hydrochloric acid (1–1). Tests made of this soluble matter showed that by far the greater proportion consists of calcium carbonate.

wise no indication of incorporated crust material.

The lower 14 feet of the 17-foot section are composed of dark-green, sticky clay having the appearance and feel of soap. Calcareous matter is present in considerable quantity throughout the section, though no quantitative tests were made. In the small samples, which were taken at intervals of from 1 to 4 feet, there is no apparent lamination.

Locality B (*Table 2*).—In this 3-foot profile there is little variation from bottom to top. The water-soluble salts are present in only a very small amount (2.5 per cent to 4.2 per cent), but one-fourth of the sample consists of acid-soluble material. The latter does not appear to be present in the form of visible shell material. The upper part of the profile shows nearly twice as much silt-clay as sand-silt, but the lower part shows an increase (37.3 per cent to 59.1 per cent) of the latter. No true sand is visible in the profile. Especially conspicuous is the large amount of shrinkage which takes place when the wet clay dries out completely. There is no evidence in this profile of lamination, nor of the crust material observed elsewhere by Antevs on some of the dry lake bottoms.

When compared with the sediments from Locality A, some 8 miles south, this profile contains less water-soluble matter, essentially the same amount of calcareous material, and the same general downward increase of the sand-silt fraction.

TABLE II. *Data concerning sediments at Locality B, Summer Lake, Oregon*

Location (Antevs).—B—Two and one-half miles SSE. of Summer Lake village, three-fourths of a mile from recent shore. No shells, no vegetation. Foot sinks 2 inches.

Notes on sediments (Antevs).—At surface, 1 to 5 mm. of white salt crust. Section downward from surface: (1) brown massive clay, 15 inches; (2) lead-colored, massive clay, soft as green soap, 2 feet.

Notes on sediments (Shrock).—From surface downward: (1) light-brown to gray, massive clay which shows only slight shrinkage on drying. It is somewhat crumbly toward the top. 15 inches. (2) lead-colored massive clay which is soft like green soap but which becomes hard and lighter in color on drying. The shrinkage is quite large. 21 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*
Depth below surface in ins.	0–5	11–15	20–25	31–36
H_2O Soluble	4.2	4.1	2.5	3.4
HCl Soluble	24.7	26.2	27.8	27.4
Sand-Silt	37.3	35.0	55.2	59.1
Silt-Clay	62.7	65.0	44.8	40.9

LAKE ABERT

Lake Abert, which is shown by Waring to be about the same size as Summer Lake (Fig. 2), was nearly dry when the sediments were collected in 1931. The basin in which the recent lake lay is restricted on the east by a precipitous escarpment which rises some 2,000 feet above the level of the lake, and on the other sides by more gentle slopes which lead upward from the flat basin floor to higher land. The main drainage enters at the south end of the lake and has its origin in the high, dissected country to the west and southwest. It is quite likely that Lake Abert was once connected with Summer Lake by a body of water which covered the present Chewaucan Marsh (Fig. 2).

Both profiles were obtained from the south end of the lake. The snowy whiteness observed and recorded by Antevs is due to a very thin crust of white salt at the surface. This material tastes quite salty and can be almost completely dissolved in water. When an untreated sample is treated with cold hydrochloric acid, however, there is violent effervescence for a very short time showing that there is some calcareous matter present.

Locality A (*Table 3*).—In this profile there is a gradual increase (7.7 per cent to 19.2 per cent) in the water-soluble salts from the surface downward for the first $2\frac{1}{2}$ feet, but at the base of the 3-foot section the amount drops to 2 per cent. The calcareous matter increases from 16.5 per cent at the surface to 32.5 per

cent at a depth of 1½ feet, but below that depth gradually decreases to about the same amount as at the surface. The top and bottom 3 inches contain a high sand-silt fraction (88.5 per cent to 82.5 per cent respectively).

TABLE III. *Data concerning sediments at Locality A, Lake Abert, Oregon*

Location (Antevs).—A—One and one-half miles from south end of lake and 400 yards from west shore. No shells. No vegetation. Since about five years nearly dry. As far as the eye could reach from a hillock near the southern end its bottom was dry and snowy white. Only near the southern end a few small sheets of water. Lake bottom is rather soft, so that the foot sank one-half to 1 inch.

Notes on sediments (Antevs).—At surface, 1 mm. of white salty crust. Section downward from surface: (1) gray brown sand, 2½ inches; (2) yellow massive silt, 1½ inches; (3) blue-green massive clay-silt, 2½ inches; (4) silty clay, mostly finely laminated (varved?). Laminæ 1 to a few mm. thick, 15½ inches; (5) ink-black sandy clay, laminated, but probably not varved, 11 inches; (6) ink-black sand, 3½ inches.

Notes on sediments (Shrock).—In the 15½ inch unit, numbered (4) above, a great amount of shrinkage occurs on drying. The material breaks with conchoidal fracture, and also separates into layers along the laminations. Unit (5) is light-gray sandy clay, thinly laminated, but without indication of varving. There is great shrinkage on drying with the material breaking into small chips. The upper 2 inches are transitional to the overlying unit. The lower 3½ inches of the section consist of alternating laminations of iron-stained sand and clay.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*
Depth below surface in ins.	0–2½	7–16	23–27	33–36
H_2O Soluble	7.7	12.5	19.2	2.0
HCl Soluble	16.5	32.5	23.7	17.1
Sand-Silt	88.5	56.1	37.6	82.5
Silt-Clay	11.5	43.9	62.4	17.5

An attempt was made to count the laminations in the 15½-inch unit but no satisfactory results could be obtained, due to the fact that part of the lamination is largely a matter of texture (alternating layers of clay and sand) without any definite succession. Some of the laminations in the upper 6 inches consist of alternating light and dark bands 1 to 2 mm. thick and may represent true varves. That part of the unit from 5½ to 7½ inches below the top has no observable lamination.

Locality B (*Table 4*).—Profile B, taken 1½ miles northeast of A, shows the same general increase of water-soluble salts downward from the surface (6.7 per cent to 21.9 per cent) to a depth of 2½ feet, below which the percentage decreases to 11.8 per cent; the same general abundance and occurrence of calcareous matter, except that the lowest sample in this profile shows much more than any of the other three (this increase may be due to the presence of shell matter though none was observed); and the same high percentage (83 per cent and 86 per cent) of sand-silt material in the uppermost and lowermost samples. This profile, however, does not show the lamination present at A except at the very base. Here there is a series of alternating thin sandy seams and thicker bands of sticky green clay. When dried out the sediment parts along the sandy seams and separates into thin plates. In both profiles the dark-colored, sticky clay seems to be composed of about half sand-silt and half silt-clay.

TABLE IV. *Data concerning sediments at Locality B, Lake Abert, Oregon*

Location (Antevs).—One-half mile NE. of profile A, three-fourths mile from shore.

Notes on sediments (Antevs).—At surface, 1 mm. of white salty crust. Section downward from surface: (1) brown clayey sand, 2 inches; (2) gray sand, 2½ inches; (3) silty clay, 1 foot; (4) ink-black clay, appearing mostly massive, but at least partly laminated, 3 feet; (5) black, clayey sand, 1½ feet. Water at 4 foot depth. Borer stopped at 6 feet.

Notes on sediments (Shrock).—From surface downward: (1) gray sandy clay, 2½ inches; (2) gray and dark-colored sand, 2½ inches; (3) almost black, very fine-grained clay which cuts like butter and shrinks considerably on drying, 7 inches; (4) yellowish-brown clay with some thin sandy layers, 8 inches; (5) dark, massive clay which cuts like wax or butter and shrinks greatly on drying. The fracture is smooth. In a moist condition

the clay is sticky and plastic. 18¾ inches. (6) gray laminated clay showing very little difference from the overlying material, 9¼ inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*
Depth below surface in ins.	0–5	11–16	24–29	40–48
H_2O Soluble	6.7	16.4	21.9	11.8
HCl Soluble	17.9	36.6	25.6	46.2
Sand-Silt	83.4	76.2	43.4	86.0
Silt-Clay	16.6	23.8	56.6	14.0

CRUMP LAKE (*Table 5*)

Crump Lake, according to Antevs' notes "is the lake 3 miles N. of Pelican Lake, No. 9" (Fig. 2). Apparently it is a remnant of the larger Warner Lake just to the north. Water-soluble salts are conspicuously absent in the profile. The calcareous matter increases downward, from 13.3 per cent at the surface to 19.5 per cent at a depth of 2½ feet, but falls again to 15.2 per cent at the base of the 3-foot section. This is essentially a duplication of the condition found in Lake Abert 26 miles to the northwest. The 10½-inch unit at the top of the profile is a very interesting sediment. It is gray in color, very light in weight, has a slightly rough feel, and cuts very easily and smoothly when dry. The several sandy bands which occur in the profile probably represent materials washed in at times of unusually large precipitation.

TABLE V. *Data concerning sediments from Crump Lake, Oregon*

Location (Antevs).—Crump Lake is the lake 3 miles N. of Pelican Lake, No. 9. It is not known to dry out. In 1931 lower than ever. In 1931 shrunk to a remnant along the west side of the basin, to a water body 1½ miles long, in N. and S. direction, and on an average 200 yards wide. Profile 300 yards N. of lake remnant and 300 yards from west shore, *i.e.*, 7½ miles N. of Adel.

Notes on sediments (Antevs).—From surface downward: (1) gray-white, very light sediment, that is dry and cuts very easily—a gyttja. Two troughs of same bed. Sediment is by drying cracked up in irregular, mostly oblong cells, whose long axis is from the shore, from E.–W. At the profile the cells frequently were 1½ feet long and three-fourths of a foot wide. The cracks were 2 to 5 inches wide and extended to the bottom of the bed, 1 foot. Thus one-third to one-fourth of the volume was lost. Near the shore the cells were somewhat smaller, the cracks narrower, and their depth less—8 to 6 inches. At the surface and just below, numerous shells of some large bivalve (*Unio?, Anodonta?*) as found in Pelican Lake. Some plants were growing in the cracks and on the surface. (2) sandy clay with pebbles—wash from a cloudburst, 2 inches. (3) greenish clay, so tough that it is difficult to dig in it, 2 feet.

Notes on sediments (Shrock).—From surface downward: (1) gray, very light sediment which cuts very easily when dry, 10½ inches; (2) sand and clay, 3 inches; (3) crumbly, brownish to dark-colored clay which shrinks little on drying, 16 inches; (4) slightly sandy clay with minute yellow dots or splotches, 2½ inches; (5) same as (3), 4 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*
Depth below surface in ins.	0–7	10–13	21–27	30–32
H_2O Soluble	1.3	0.0	0.0	0.0
HCl Soluble	13.3	16.4	19.5	15.2
Sand-Silt	48.7	31.9	37.8	72.0
Silt-Clay	51.3	68.1	62.2	28.0

PELICAN LAKE (*Table 6*)

Pelican Lake lies just south of Crump Lake and was at one time undoubtedly connected with it. According to Antevs, Pelican Lake has been dry every summer for the last ten years. The 3-foot profile shows no visible sand and there is some lamination in the lower 7 inches. The same lack of water-soluble salts is noticeable in this section as in Crump Lake. There is also a very small increase (26.0 per cent to 32.1 per cent) of calcareous matter from the surface downward as far as the profile extends. Unlike the Crump Lake profile, there is a gradual increase (57.1 per cent to 75.4 per cent) of silt-clay downward from the surface. The laminations do not appear to be varves. Below the laminated unit there are 2 feet of light-brown silt which dries

to a crumbly condition and contains very little calcareous matter. The samples, however, were too small for a detailed analysis.

TABLE VI. *Data concerning sediments from Pelican Lake, Oregon*

Location (Antevs).—23 miles E. of Lakeview, Oregon. Dry every summer for the last ten years. No vegetation. Shells of very large bivalve at surface and down to depth of 6 inches. Profile 300 yards out from western shore.

Notes on sediments (Antevs).—From surface downward: (1) white-gray flaky clay, three-fourths of an inch; (2) gray massive silty clay, 2 inches; (3) brown clay, 2½ feet; (4) yellow clay, 2 feet. Water at depth of 5 feet.

Notes on sediments (Shrock).—From surface downward: (1) light-colored, silty clay which shows little shrinkage on drying, and is less crumbly than underlying material, 5 inches; (2) gray, light-brown, crumbly clay which shows practically no shrinkage on drying, and presents a massive appearance, 24 inches; (3) light-yellow laminated clay with laminations about 1 mm. in thickness, and varying from the overlying material in not becoming crumbly, 7 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*
Depth below surface in inches	0–5	14–19	32–36
H_2O Soluble	0.2	0.0	0.2
HCl Soluble	26.0	27.2	32.1
Sand-Silt	42.9	38.1	24.6
Silt-Clay	57.1	61.9	75.4

GOOSE LAKE (OREGON-CALIFORNIA)
(*Table 7*)

Goose Lake lies partly in Oregon but mainly in California (Fig. 1). The profile was taken from the northern end of the lake just north of the boundary line between the states (Fig. 2). The basin is bounded on its eastern margin by a high range roughly parallel with it and rising over 3,000 feet above the lake; around its northern and northwestern margins by a much dissected upland; and along its western and southern borders by a fairly flat upland surface which lies 200 to 400 feet above the lake. The drainage into this large lake, nearly 30 miles long north and south and 9 miles wide, comes from all directions. The mountainous country to the northwest and to the south, however, furnishes the principal part. There are a few small streams flowing into the lakes from the high range to the east.

The profile was collected in 1931 when the lake was entirely dry. Antevs reccorded in his notes that "1 mile S. of the State Line and 1 mile out from the east shore a well was sunk in the fall of 1931 to a depth of 800 feet." The sediments encountered consisted mainly of silty clays and clay, apparently not much unlike those obtained in the profile. The material in the profile shows no characteristic difference from top to bottom.

TABLE VII. *Data concerning sediments from Goose Lake, Oregon*

Location (Antevs).—Entirely dry in 1931. Profile just N. of California-Oregon state line, 1½ miles out from east shore. Covered by a bushy plant.

Notes on sediments (Antevs).—From surface downward: (1) dry, powdery clay, 1½ feet. There is no real crust. The wheels sink 1 to 2 inches. At surface and to depth of 1 foot numerous shells. (2) clay, like green soap, 4½ feet. (3) soft clay with plenty of water, 3 feet. (4) rather hard clay, 2 feet. One mile south of State Line and 1 mile out from the east shore a well was sunk in the fall of 1931 to a depth of 800 feet. All the way it was through the same silty clay and clay. No water was found.

Notes on sediments (Shrock).—From surface downward: (1) gray powdery to crumbly clay containing considerable vegetable and shell matter, 19 inches; (2) light-gray (greenish when wet) massive clay which breaks into irregularly-shaped blocks with conchoidal fracture upon drying. This unit shows more shrinkage on drying than the overlying material. 17 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*
Depth below surface in inches	14–19	32–36
H_2O Soluble	1.2	0.6
HCl Soluble	37.0	38.0
Sand-Silt	44.6	48.8
Silt-Clay	55.4	51.2

The water-soluble salts are negligible in amount, but the calcareous matter is present in rather large amount (37 per cent to 38 per cent), due very likely in part to shell matter. As would be suspected from the nature of the sediment the sand-silt and silt-clay fractions are about equal.

THE CALIFORNIA LAKES

The southern two-thirds of Goose Lake, to which reference has already been made, Upper Lake, Middle Alkali Lake, Horse Lake and Honey Lake lie in California. All of these lakes are located in the extreme northeastern corner of the State and are arranged in a general north-south alignment as seen in Fig. 1. The first three lie almost wholly in the Alturas Quadrangle; the last two lie in the Honey Lake Quadrangle. Drainage details are shown in Figs. 3 and 4.

Upper Lake and Middle Alkali Lake, both elongated north and south, lie in a long north-south trending valley bordered on the east and west by high ranges which rise from 2,500 to over 5,000 feet above the lakes. The drainage is mainly from the western range, but there are several streams from the eastward also. It seems very likely that both lakes, as well as Lower Lake, were connected a short time ago geologically.

Horse Lake is surrounded on all sides by peaks of volcanic materials. These rise 1,000 feet or more above the lake basin. The drainage into the lake is radial and of local origin. Honey Lake lies in an extensive flat-bottomed basin bounded along its southwestern border by an escarpment that rises 3,000 feet above the lake; and along its other borders by several conical peaks of volcanic materials. These tower over 4,000 feet above the general level of the basin. In addition to the Tertiary volcanics there are also some more ancient volcanics and sediments in the vicinity of both Horse and Honey lakes. The drainage into the latter comes mainly from the north and west (Fig. 4).

UPPER LAKE (*Table 8*)

The profile was taken at about the middle of the western margin of the lake (Fig. 3). The samples were not large enough to analyze quantitatively. Most of the sediment effervesces considerably, and in some cases violently, when treated with cold hydrochloric acid, indicating that there is considerable calcareous matter present. No lamination appears in the samples.

TABLE VIII. *Data concerning sediments from Upper Lake (Alturas Quadrangle), California*

Location (Antevs).—Profile 7½ miles S. of Fort Bidwell, 3 miles S. of highway junction at Fandango Pass, one-fourth mile from recent lake shore. No shells, no vegetation. Dry every summer for last 20 years.

Notes on sediments (Antevs).—From surface downward: (1) white clay forming a hard surface (Vial 1), 1 inch; (2) massive, very tough clay (Vial 2 from middle of bed), 2 feet; (3) clayey sand, hard packed, (Vial 3), 3 inches; (4) ink-black stinking sediment, dry and tough, and so hard that borer could not be driven through it (Vial 4 at top and Vial 5 at depth of 1 foot in bed), 1 foot.

Notes on sediments (Shrock).—From surface downward: Vial 1 contained a gray-white clay which effervesced violently when treated with dilute hydrochloric acid. The clay became flocculent after acid treatment. Vial 2 contained a tough brown clay containing some calcareous material, but the effervescence was not as violent as in the overlying material and did not continue as long. The flocculated clay settled quickly. Vial 3 contained silt with very little calcareous matter. Vial 4 contained light-gray calcareous clay. When treated with dilute acid there was violent effervescence for an instant and then the action ceased. Vial 5 contained clay similar to that in Vial 4. Samples from the vials were not quantitatively analyzed because of their small size.

MIDDLE ALKALI LAKE (*Table 9*)

Water soluble salts are present in very small amounts (1.6 per cent to 5.8 per cent) but the usual 25 per cent or more of calcareous matter is present. The upper 5 feet of the profile show considerably more silt-clay than the top of the lower 4 feet (58.8 per cent and 66.5 per cent as compared to 31.0 per cent). It is quite

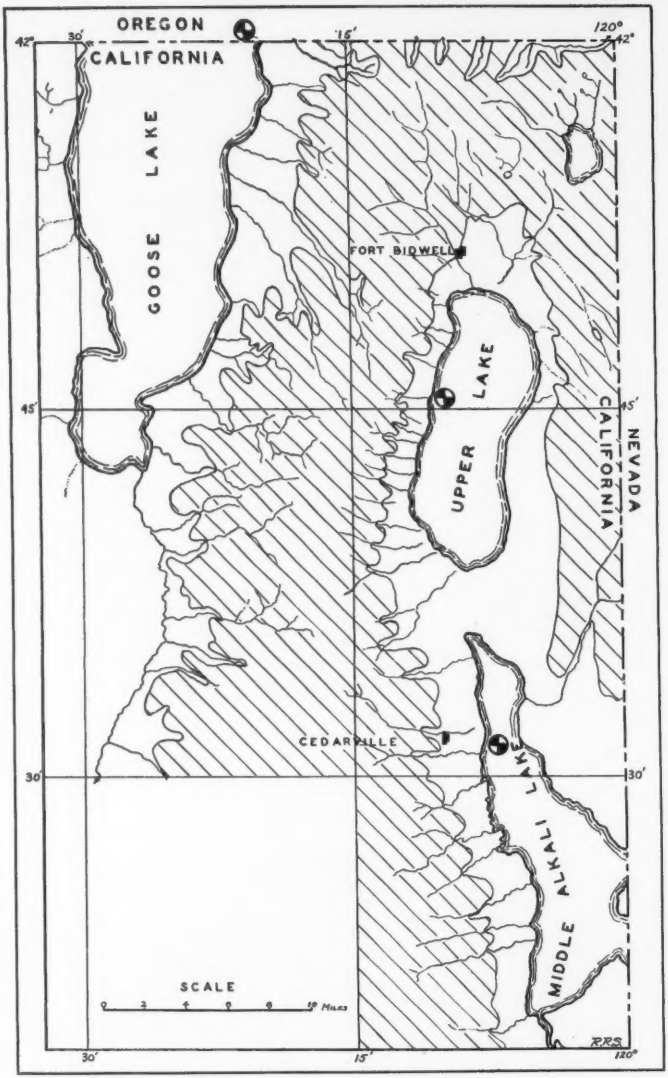

FIG. 3. Map showing the location and relations of Goose Lake, Upper Lake and Middle Alkali Lake, California. The locations of the profiles are indicated by partly filled circles; the highland areas by oblique lining. (Base map after *U. S. Geol. Survey, Alturas, California, Sheet* 1892 [1931].)

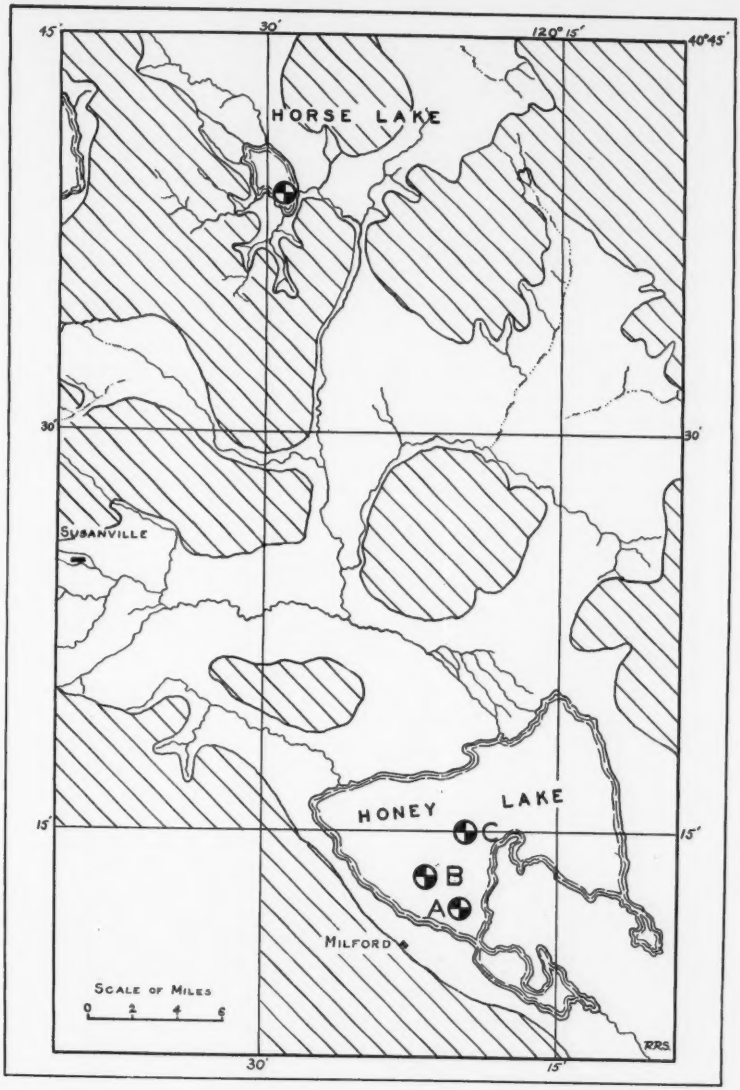

FIG. 4. Map showing the location and relations of Horse Lake and Honey Lake, California. The locations of the profiles are indicated by a partly filled circle; the highland areas by oblique lining. (Base map after *U. S. Geol. Survey, Honey Lake, California, Sheet,* 1893 [1909].)

probable, however, that this percentage increases downward from the top of the lower 4½ feet, for the sediment is a green soapy clay which in other profiles has shown well over 50 per cent of silt-clay material. The lower 4½ feet also show considerable calcareous matter. No lamination appears in the profile.

TABLE IX. *Data concerning sediments from Middle Alkali Lake (Alturas Quadrangle), California*

Location (Antevs).—Profile 3 miles ESE. of Cedarville, a little E. of medial line of lake. Surface dry and soft. No shells, no vegetation. Completely dry every summer during the last 10 to 15 years. Some water in spring.

Notes on sediments (Antevs).—From surface downward: (1) clay, 1 foot. At surface gray, very loose, becoming yellow and more compact downwards. (2) yellow clay, soft as butter, with approximate thickness of 3 to 4 feet. (3) ink-colored stinking sediment, 4½ feet. (4) hard layer not penetrable by borer.

Notes on sediments (Shrock).—From surface downward: (1) yellow-gray, massive clay drying to a crumbly condition with some shrinkage, and with the upper 2½ inches like dust, 12 inches. (2) dark-gray massive clay, quite soft and can be cut like butter. Shows considerable shrinkage on drying and is not much different from the underlying material except for being slightly more crumbly on drying. The lower 3 inches slightly yellow in color. The sample is 15 inches thick and was taken at the top of the 3 to 4 foot section. (3) dark massive clay showing considerable shrinkage on drying, and breaking conchoidally into pebble-like or spheroidal fragments, 9 inches. The sample was taken at the top of the 4½ foot unit.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*
Depth below surface in inches	3–10	12–26	60 ± –69 ±
H_2O Soluble	1.6	5.8	3.1
HCl Soluble	28.9	28.6	28.6
Sand-Silt	41.2	33.5	69.0
Silt-Clay	58.8	66.5	31.0

HORSE LAKE (*Table 10*)

In this very shallow section there are practically no water-soluble salts but the calcareous matter reaches the unusually high figure of 44.9 per cent. It should be noted further that this profile, which shows a high content of calcareous matter, also carries a high percentage (74.6 per cent) of silt-clay material. Very likely much of the silt-clay fraction is in the form of finely divided calcium carbonate, for it was observed that samples in which a long settling period was required during the separation of the water-soluble salts cleared fairly rapidly when treated with hydrochloric acid.

TABLE X. *Data concerning sediments from Horse Lake (Honey Lake Quadrangle), California*

Location (Antevs).—Nineteen miles NNE. of Susanville. Dry, probably since several years, for most of the bottom is grass-covered. Car wheels sank 1 to 2 inches. Profile one-half mile W. of mouth of now dry brook on the east side.

Notes on sediments (Antevs).—From surface downward: (1) tough massive clay, 3 feet; (2) tough clay, cemented by iron, 6 inches.

Notes on sediments (Shrock).—From surface downward for 1 foot: gray crumbly clay which shows only moderate shrinkage on drying.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*
Depth below surface in inches	3–6
H_2O Soluble	0.7
HCl Soluble	44.9
Sand-Silt	25.4
Silt-Clay	74.6

HONEY LAKE (*Table 11*)

Profile A is the only one of the three from which samples were collected (Fig. 4). The content of water-soluble salts is negligible (1.2 per cent to 1.5 per cent). The usual 25 per cent of calcareous matter is present, and with the exception of the second 6-inch unit from the top, which is somewhat more sandy, the sand-silt and silt-clay fractions are about equal. This is to be expected for there are no conspicuous bands of either sand or clay in the profile. In localities B and C, however, Antevs reported several feet of "yellow massive silty clay with streaks

TABLE XI. *Data concerning sediments at Locality A, Honey Lake (Honey Lake Quadrangle), California*

Location (Antevs).—A—Three miles NE. Milford, and 1 mile from shore. Dry since 1924. Car wheels sank one-half to 1 inch. No vegetation. No shells.

Notes on sediments (Antevs).—From surface downward: (1) *yellow-gray clay, 6 inches;* (2) yellow-brown clay with rusty layers and with alternating brown and white laminae, *1 foot; (3) yellow-brown massive, silty clay,* 3 feet. Fossil fish 3 feet below surface.

Notes on sediments (Shrock).—From surface downward: (1) yellow-gray clay, which dries with little shrinkage into a crumbly condition, 6 inches. (2) yellow-brown clay with upper 6 inches composed of alternating brown and white laminae, and lower 3 inches with *rusty bands but with little in the way of* lamination. The 6 inch unit shrinks somewhat on drying and becomes disintegrated into small chips. The 3 inch unit remains massive. 9 inches. (3) light-gray shale, having a laminated appearance because of alternating gray and white bands. The material is slightly micaceous and undergoes little shrinkage on drying. 4 inches. (4) yellowish massive clay, with a few iron-stained bands. There is little shrinkage on drying. The material crumbles easily between the fingers when dried out. It is similar to the 3 inch unit of (2). 5 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*
Depth below surface in inches	1–5	7–10	15–19	21–24
H_2O Soluble	1.5	1.4	1.5	1.2
HCl Soluble	24.2	28.0	23.2	25.6
Sand-Silt	42.4	66.2	50.6	45.0
Silt-Clay	57.6	33.8	49.4	55.0

of mud." There is some lamination in Profile A, as well as in B and C, but it not of the varved character. The banding appears to be due to alternating brown and white layers.

THE NEVADA LAKES

Humboldt Lake, Carson Lake and Carson Sink lie in Nevada. All of the profiles studied were collected from the Carson Sink Quadrangle (Fig. 5). The three lakes lie in one great flat-bottomed, northeast-southwest trending basin bounded on both sides by narrow mountain ranges that rise from 1,000 to over 4,000 feet above the level of the lakes and trend parallel with the basin. Carson Sink is separated from Humboldt Lake by Humboldt Range which rises over 1,500 feet above the lakes. Carson Sink and Carson Lake are connected by a stream which furnishes water for the Fallon district. One profile was taken northwest of Leeteville but at present there is no lake occupying the site (Fig. 5).

The Nevada lakes are surrounded by and lie in a terrane of both igneous (*mainly volcanic*) and sedimentary rocks. The former are mainly of Tertiary age but there are some younger and some older effusives. Mesozoic and Cenozoic sediments are found in patches throughout the general region. From this faulted terrane has come the sedimentary material in the lakes.

HUMBOLDT LAKE (*Tables 12, 13*)

The profiles were taken from the points indicated in Fig. 5. The lake has been entirely dry since 1926, hence the sediments collected in 1931 were obtained from the dry lake bottom. Humboldt Lake is bordered on both the east and west sides by high ranges which rise over 1,000 feet above the basin. The basin is connected with the larger one to the southeast through a gap at the south end of Humboldt Range.

Locality A (*Table 12*).—This profile shows an unusually large content of water soluble salts at the surface (19.3 per cent) as well as a fairly high percentage in the deeper samples (9.7 per cent to 15.9 per cent). The small percentage in the sample 1½ feet below the surface may be due to the concentration of some of its original content at the surface to give the unusual amount there. The content of calcareous matter in the profile is almost twice as much as is found in the nearby lakes. The lowest percentage (36.7 per cent) is found in the surface sample. From 1½ feet below the surface to the base of the 6-foot section there is a gradual decrease from 57.9 per cent to

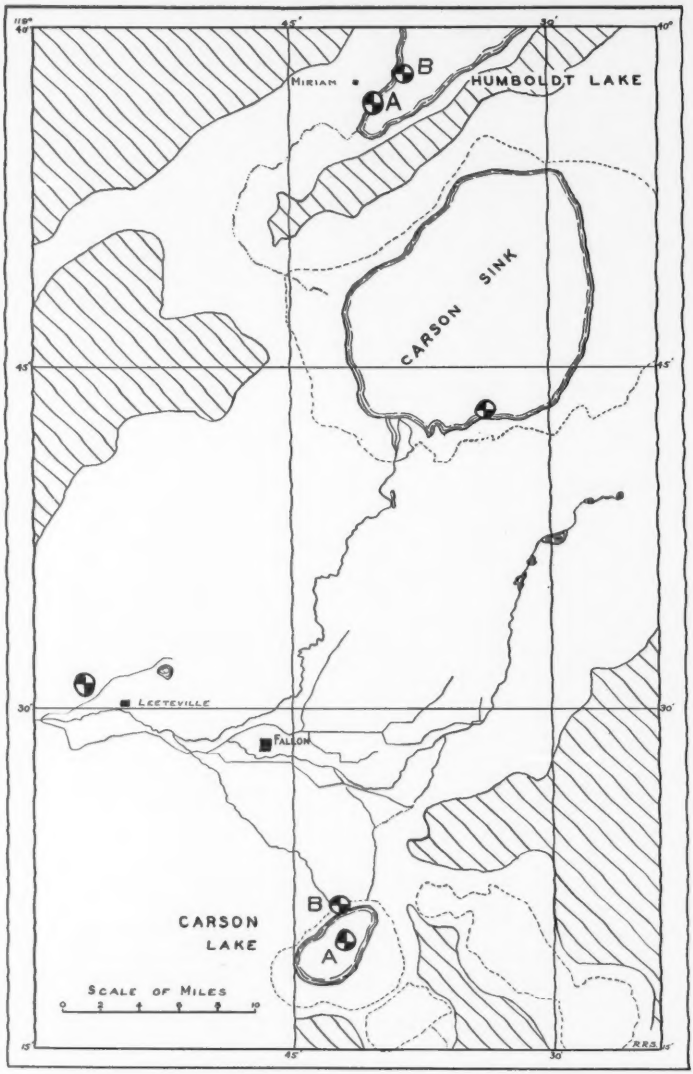

FIG. 5. Map showing the location and relations of the Oregon lakes from which profiles were collected. The locations of the profiles are indicated by partly filled circles; highland areas by oblique lining. (Base map after *U. S. Geol. Survey, Carson Sink, Nevada, Quadrangle,* 1910 [1922].)

TABLE XII. *Data concerning sediments at Locality A, Humboldt Lake, Nevada*

Location (Antevs).—One mile ESE. of Miriam Siding, 400 yards out from shore. Entirely dry since 1926. U. S. Quadrangle incorrect; recent lake shore close to railroad. No vegetation.

Notes on sediments (Antevs).—At surface, one-fourth to one-third inch surface crust with some salt. From surface downward: (1) massive, somewhat granular yellow-brown clay, the upper 3 to 6 inches of which are dried to dust, 2 feet; (2) yellow clay with fragments of the varved? sediment that occurs below, 1 foot; (3) varved? sediment, consisting of alternating white and greenish layers, 1½ to 2 inches; (4) finely laminated (varved?) yellow-brown clay, 16 inches; (5) sandy, massive clay, 1 foot; (6) gray-brown massive, very sticky clay which cuts like butter, 2 feet. Bottom of similar material not reached at 7 feet below the surface.

Notes on sediments (Shrock).—From surface downward: (1) dark-gray crumbly clay, which is dust in the upper 4 to 6 inches, and which is somewhat granular, 16 inches; (2) light-colored, fine-grained clay which breaks with conchoidal fracture into small fragments, and does not shrink greatly on drying, 22 inches; (3) very thinly laminated, greenish clay, with the laminations averaging about 1 mm. in thickness (110 bands were counted but there were certainly more for the cracked condition of the clay made an accurate count impossible), 10 inches; (4) light-colored (gray-brown when not dry), fine-grained clay, crumbly and slightly gritty in the upper foot, and containing numerous small shells in the lower foot, 2 feet.

Analysis of samples in per cent (Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*	*E*
Depth below surface in inches	5–10	21–28	40–47	50–57	63–70
H_2O Soluble	19.3	9.7	12.2	10.7	15.9
HCl Soluble	36.7	57.9	50.4	48.9	37.5
Sand-Silt	19.5	22.4	81.5	29.7	46.6
Silt-Clay	80.5	77.6	18.5	70.3	53.4

37.5 per cent. So far as could be determined, none of the calcareous matter is due to the presence of visible shell matter. The percentages of sand-silt and silt-clay show considerable variation without any definite succession. The 10-inch laminated unit was much cracked as a result of desiccation and it was not possible, therefore, to make an accurate count of the laminations, but over 110 could be made out. The writers would hesitate to call these laminations varves, although they may be.

Locality B (*Table 13*).—The profile taken at B differs from that at A in having a very small percentage of water-

TABLE XIII. *Data concerning sediments at Locality B, Humboldt Lake, Nevada*

Location (Antevs).—Two and one-half miles NE. of Miriam Siding, nearly 2 miles from shore. Profile just E. of a river channel on lake bottom. Lake bottom hard as a road. On it are to be found numerous pebbles and cobbles. Also Indian grinding stones, chips of flint, etc. All this on *surface*. Stones probably washed out during cloudburst.

Notes on sediments (Antevs).—From surface downward: (1) gray clay, same as below, which is hard as a road, 9 inches; (2) gray massive clay getting darker downward [this is a gray marly clay containing some shell matter], 1 foot; (3) light-gray massive clay, heavily charged with shells [a marly clay which shows little shrinkage on drying], 34½ inches; (4) varved? sediment, in laminations 1 to 2 mm. thick, the bottom of which unit was not reached at 7 feet below the surface [this material disintegrated so much on drying that the laminations could not be counted], 25½ inches.

Analysis of samples in per cent (Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*	*E*
Depth below surface in inches	9–12	30–34	48–52	55–59	76–80
H_2O Soluble	2.4	0.9	0.5	0.5	0.5
HCl Soluble	74.6	45.6	45.0	37.5	39.1
Sand-Silt	49.5	25.9	32.2	43.3	55.9
Silt-Clay	50.5	74.1	67.8	56.7	44.1

soluble salts, and these are mainly concentrated at the surface where 2.4 per cent are present. In the remainder of the 6-foot section there is less than 1 per cent. A second difference is apparent when the calcareous content is considered. The surface sample shows the unusually large percentage of 74.6 per cent. Part of this may be due to invisible shell substance. There is a gradual decrease downward, but even at the base of the profile there is still over 39 per cent present. With the exception of the sample at 30 inches below the surface, the sand-silt and silt-clay fractions are about equal. The lamination present in the section could not be studied in detail because of the disintegrated condition due to desiccation. A cursory examination was sufficient to show that they are not true varves.

CARSON SINK (*Table 14*)

Carson Sink was entirely dry when the profile was collected in 1931. In the section there is considerable water-soluble matter at and near the surface, but in the lower 1½ feet of the profile the percentage drops to slightly more than 1 per cent (13.1 per cent to 1.1 per cent). The usual content of calcareous matter is present in the clays and silts (28 per cent to 38 per cent), but it drops to nothing in the sandy layer at the base of the section.

HAZEN LOCALITY (*Table 15*)

The sediments collected northwest of Leeteville were taken within 1 foot of the surface and hence give little information concerning the character of the deposit. There is a decided concentration of the

TABLE XV. *Data concerning sediments from Hazen, Nevada*

Location (Antevs).—Six miles SE. of Hazen and 2 miles NW. of Leeteville, on highway. Playa with salt crust, no shells and no vegetation.

Notes on sediments (Shrock).—From surface downward: (1) dirty-gray, massive clay which becomes slightly crumbly on drying, 12 inches.

Analysis of samples in per cent (Shrock and Hunzicker)

Sample	*A*	*B*
Depth below surface in inches	0–2	10–12
H_2O Soluble	8.3	0.4
HCl Soluble	27.7	27.3
Sand-Silt	86.6	34.4
Silt-Clay	13.4	65.6

TABLE XIV. *Data concerning sediments from Carson Sink, Nevada*

Location (Antevs).—SE. of C in Carson Sink, U. S. Geol. Survey, Carson Sink Quadrangle, and one-half mile from recent shore. No vegetation. Entirely dry in 1931. As other large temporarily dry lakes it has a bottom practically as level as a smooth water surface.

Notes on sediments (Antevs).—From surface downward: (1) yellow-white sandy clay, dried to form a crust, 3 inches; (2) sediment like butter or green soap in consistency, and in upper part there is sandy clay (same as surface crust) which becomes very stiff downward, 3 feet; (3) rusty stratified sand, sharply marked from overlying material and having water coming up out of it, 2½ feet.

Notes on sediments (Shrock).—From surface downward: (1) greenish, massive silt and clay, definitely separated from the underlying unit by a more disintegrated appearance on drying (being somewhat crumbly), and being somewhat lighter in color, 18 inches, (2) greenish, massive silt, fairly fine-grained, showing much shrinkage on drying. The material breaks into irregular pieces with conchoidal fracture. The unit is somewhat sandy, but is sharply separated from the underlying sand. 23 inches. (3) iron-stained micaceous sand, 19 inches.

Analysis of samples in per cent (Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*	*E*	*F*
Depth below surface in inches	0–3	10–14	18–26	33–41	41–45	58–60
H_2O Soluble	5.0	12.7	13.1	8.7	1.1	1.3
HCl Soluble	28.2	33.3	34.6	38.3	8.6	0.0
Sand-Silt	48.2	41.8	44.4	82.2	92.7	97.4
Silt-Clay	51.8	58.2	55.6	17.8	7.3	2.6

water-soluble salts at the surface as compared to the quantity present at 1-foot depth (8.3 per cent as compared with 0.4 per cent). The usual content of calcareous matter is present (27 per cent), and the surface sediments are more sandy (86.6 per cent sand-silt) than those at the base of the profile (34.4 per cent sand-silt).

CARSON LAKE

This small lake, dry at the time the profiles were taken in the summer of 1931, lies along the eastern edge of the large basin in which Carson Sink and Humboldt Lake lie farther to the north. To the eastward it is separated from another extensive basin by a narrow range. The drainage into the lake comes from the north (Fig. 5).

Locality A (*Table 16*).—Profile A, which was taken near the center of the dry lake bed, shows only a trace of water-soluble salts (1.7 per cent to 0.1 per cent). The calcareous matter decreases downward from 23.3 per cent at the surface to 12.9 per cent at the base of the 4-foot section. The marked decrease in the lower 16 inches is undoubtedly due to the sandy character of the sediment. The usual fairly evenly divided sand-silt and silt-clay materials are present in the typical clay sediments, but there is an increase in the sand-silt fraction where the sediment becomes sandy, as at the base of the profile where the percentage rises to 92 per cent.

Locality B (*Table 17*).—Profile B shows the same paucity of water-soluble salts as A, but differs strikingly from that profile in having a very small content of calcareous matter (5.8 per cent to 10.7 per cent). This is apparently due to the fact that the sediments are very sandy, as is shown by the high percentages of the sand-silt fraction (82 per cent to 90 per cent). This should be the case, as Profile B was taken along the recent shoreline whereas A was collected from the middle of the basin (Fig. 5).

Some interesting facts may be pointed out concerning the sediments of the lakes in the Carson Sink-Carson Lake basin. The percentage of water-soluble salt is generally negligible, except in Profile A of Carson Lake, where the location of the profile may have some significance (i.e., being in the middle of the lake basin rather than along the shore as is the case with the other sections); and in Carson Sink where considerable material is concentrated near the surface. Calcareous matter is present in large quantities (22 per cent to 74 per cent) in all of the typical lake clays and silts of the region. Unusually large percentages are found in the

TABLE XVI. *Data concerning sediments at Locality A, Carson Lake, Nevada*

Location (Antevs).—At L. in Carson Lake, U. S. Geol. Survey, Carson Sink Quadrangle Shells and dense vegetation. Entirely dry since July, 1929.

Notes on sediments (Antevs).—From surface downward: (1) stiff clay, 1½ feet; (2) granular sediment, becoming sandy at depth of 1 foot.

Notes on sediments (Shrock).—From surface downward: (1) gray, smooth clay, breaking up easily on drying with conchoidal fracture, 12 inches; (2) gray crumbly clay, somewhat gritty, and differing from overlying and underlying units in not being smooth, 7 inches; (3) gray, fairly smooth clay, fracturing as unit (1), 5 inches; (4) gray clay, somewhat sandy toward the base, 12 inches; (5) gray sand with very little clay, 12 inches.

Analysis of samples in per cent (Shrock and Hunzicker)

Sample	*A*	*B*	*C*	*D*	*E*
Depth below surface in inches	0–2	11–13	22–26	34–36	46–48
H_2O Soluble	1.1	1.7	1.0	0.4	0.1
HCl Soluble	23.3	22.1	22.8	15.0	12.9
Sand-Silt	55.2	73.3	55.1	66.5	92.0
Silt-Clay	44.8	26.7	44.9	33.5	8.0

TABLE XVII. *Data concerning sediments at Locality B, Carson Lake, Nevada*

Location (Antevs).—One and eight-tenths miles N. of A, just N. of old dotted shore line and one-fourth mile E. of South Branch of Carson River. The place is probably 6 to 7 feet above the lowest part of the Carson Lake basin.

Notes on sediments (Shrock).—From surface downward: (1) sandy clay containing considerable vegetable matter in the form of roots, 6 inches; (2) coarse gray sand with numerous small pebbles about the size of buckshot, and containing a small amount of vegetable matter, 12 inches.

Analysis of samples in per cent
(Shrock and Hunzicker)

Sample	*A*	*B*	*C*
Depth below surface in inches	0–2	7–11	16–18
H_2O Soluble	0.0	0.0	0.0
HCl Soluble	10.7	5.8	6.7
Sand-Silt	82.0	90.0	86.1
Silt-Clay	18.0	10.0	13.9

true marls, and in the less marly sediments part of the calcareous matter is due to shell substance. If the amount of calcareous matter drops below 20 per cent, the sediments will be found to consist largely of sand and silt, not of clay. In the main the typical clays and silts of the Great Basin region have the two fractions about equally divided.

SUMMARY AND CONCLUSIONS

1. The following results are based on analyses of 58 samples of lake sediments selected from 17 profiles, ranging in thickness from 1 to 6 feet and taken from the surface downward, which were collected by Dr. Ernst Antevs during the summer of 1931. The sediments were taken from twelve Great Basin lakes lying in southeastern Oregon, northeastern California and northwestern Nevada. Many of the basins were entirely dry at the time the profiles were obtained.

2. The content of water-soluble salts present is usually small (averaging about 4 to 5 per cent) and rarely exceeds 10 per cent. Exceptions to this general statement are: (1) Carson Sink, Nevada (1.1 to 13.1 per cent); (2) Humboldt Lake, Nevada, Locality A where the content ranges from 19.3 per cent at the surface to 9.7 per cent at depth; and (3) Lake Abert, Oregon, in which both profiles show high percentages —A (2.0 to 19.2 per cent) and B (6.7 to 21.9 per cent). In both of the Lake Abert localities the largest percentages are found at a depth of 2 to 2½ feet below the surface. Upward and downward the quantity decreases.

Tests made of the salty crust, which is frequently present on dry lake bottoms, show that while the material is composed largely of salts soluble in water, some calcareous matter is usually included.

3. There is consistently present around 25 per cent or more of material soluble in cold hydrochloric acid (1–1). Rarely does the percentage drop below 20 per cent, and in almost all such cases the samples carry large quantities of quartz sand. On the other hand, numerous samples show much higher percentages (especially those from Humboldt Lake, Nevada), ranging from 38 per cent to as much as 74 per cent. In almost every case where the percentage is unusually high, considerable shell matter is present in the samples. In different profiles the percentages may increase with depth from the surface, decrease similarly, or be erratic.

Of particular interest is the fact that some of the calcareous matter is present in a very fine-grained condition. Some samples when treated with distilled water had to be left for over 100 hours before the water became clear. When these same samples were treated with hydrochloric acid, however, all of the finely divided material went into solution and the liquid cleared within ten hours or less. Furthermore, in a number of samples carrying a large content of acid-soluble matter there is also an unusually high percentage of silt-clay material. This relation does not always occur.

4. The sand-silt and silt-clay fractions exhibit such variation that no very accurate generalization can be formulated concerning them. The sand-silt content does not drop below 19 per cent in the fine-grained clays, and constitutes as much as 97 per cent of some of the sandy layers. In the typical gray massive (usually crumbly when dried) clays, and in some of the greenish soapy clays the quantities of sand-silt and silt-clay materials are approximately the same.

5. Search was made in the sediments for some indication of the crust material which, according to the notes of Doctor Antevs, is found frequently on the surface of dry lake bottoms. This material consists of flakes of dried clay which have broken loose from the underlying sediments because of shrinkage and cracking due to desiccation. When in the laboratory the clays were dried from an originally wet condition, and then again immersed in water, regardless of how hard they became on being dried, they slaked down readily and rapidly without exception. It does not seem probable, therefore, that any crust material which was once dried thoroughly would retain its shape and identity upon being covered again by water. It is thought for this reason that the absence of crust material in the profiles is due to the fact that the flakes slaked and mixed with the incoming sediments when the dry lake bottom became covered with water. It appears, therefore, that past periods of extensive desiccation can rarely if ever be detected in the lakes studied by means of the crust material.

6. The wet clays show a varying amount of shrinkage upon drying. Some dry to a crumbly condition and may be disintegrated easily. Others, especially the green soapy or sticky clays, harden greatly when they dry and show tremendous shrinkage, in some cases certainly as much as 30 per cent by volume. Upon ordinary drying in the atmosphere these latter clays break into spheroidal or pebble-like fragments with conchoidal fracture. In some of the sediments which consist of alternating thin seams of sand and thicker bands of clay, separation takes place along the junction of the two upon drying and the unit breaks up into a series of flat, tabular plates which correspond to the individual layers.

7. Four general types of sediments are found in the profiles studied. (1) Light-colored marly clays and silts which dry with very little shrinkage and are usually massive.

These usually contain shell matter. (2) Olive-green, soft soapy clays containing much calcareous material, drying with large shrinkage to a very hard condition and rarely showing lamination. (3) Laminated, light to dark or greenish clays which in some cases appear to be varved. (4) Sandy bands, with little or no slit and clay, which probably represent deposits made at times of cloudbursts.

8. Lamination was noted in several of the profiles (Lake Abert, Pelican Lake, Honey Lake and Humboldt Lake), but in no case do the writers feel certain that it may be interpreted as varving. The irregularity of the bands and the lack of consistent succession argue against such an interpretation. Furthermore, the fact that none of the profiles reached more than 17 feet beneath the surface made it impossible to study any of the more ancient beds. Deeper profiles might reveal rhythmic banding.

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THE MICROFLORA OF THE MUD DEPOSITS OF LAKE MENDOTA[1]

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ABSTRACT

This paper presents bacteriological analyses of the deposits of Lake Mendota, a fresh-water lake in Wisconsin. Samples were taken from two different stations in both winter and summer from the surface of the deposit and from the underlying marl. A varied flora was found, including most of the groups of soil microorganisms. The nitrifying and cellulose decomposing bacteria were detected only in a few instances in the surface muds.

In order to determine the part that microorganisms may play in the chemical changes which go on in natural mud deposits, a survey has been made of the number and kinds of bacteria present at different depths in the deposits of Lake Mendota, a fresh-water lake in southern Wisconsin. The microflora of the water of this lake has been studied earlier by Fred, Wilson, and Davenport, 1924. The numbers of bacteria were noted at different depths, at different seasons of the year, and under different weather conditions. Numerous observations have also been made on the nitrogen content of the lake waters and its relation to the rise and fall of plankton activity (Peterson, Fred, and Domogalla, 1925; Domogalla, Juday and Peterson, 1925; Domogalla, Fred, and Peterson, 1926; and Domogalla and Fred, 1926).

Comparatively little work has been done on the mud deposits. Black, 1929, made chemical analyses of the deposits of several Wisconsin lakes including Mendota. Allgeier, Peterson, Juday, and Birge, 1932, have studied the fermentation of lake mud under laboratory conditions at different temperatures. Little attempt was made to determine the kinds of microorganisms present during the fermentation and reference is made simply to the flora as consisting of "chromogenics, ammonifiers, denitrifiers, cellulose destroyers, and other typical lake organisms."

METHODS

The bottom of Lake Mendota, in the deeper parts, is covered by a black soupy sludge, which is believed to be one or more feet thick (Twenhofel, 1933). It becomes more dense downward and passes into a dark mud, rich in organic matter. This in turn passes into gray mud or marl, the change in appearance of the mud being rather abrupt.

The instrument used in taking all of the samples was devised by W. H. Twenhofel of the Department of Ge-

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ology. A core of the mud was secured by driving a 3-inch pipe into the bottom of the lake and then hoisting it to the surface. A sterile sheet-metal cylinder, placed within the pipe before lowering the sampler, enclosed the mud core and kept it intact: it could thus be removed and taken to the laboratory for examination. With the insertion of a second sterile cylinder, a second core was easily obtained.

The cylinders are approximately 6 feet long. It was found that they filled to about 2½ feet, even though the pipe was driven full length into the mud. This core, however, covered the range from soft black mud to the firm gray marl and it was considered sufficient to sample within this length. The samples for bacteriological analyses in the present work were taken from the dark surface mud and the gray mud below, in order to keep the laboratory work to a minimum and yet to include extremes of flora, if there should prove to be change with depth. These are the "top" and "bottom" samples respectively.

Forty-three samples were taken in all. They represent mud from two different stations, one in 65 feet of water in University Bay and the other in 80 feet of water about three-quarters of a mile north of Picnic Point. Samples were taken in both winter and summer. Moisture determinations were made on each sample and all plate counts are reckoned on the dry basis. The dilution counts however remain on the wet basis. The water content of the top samples ranged from 82 to 89 per cent and of the bottom samples from 76 to 85 per cent.

The media and methods used throughout this work are those commonly used in soil microbiology (Fred and Waksman, 1928). It was assumed that these procedures would be applicable, an assumption in fact justified by the finding in lake muds of most of the principal groups of soil bacteria.

Plate methods were used for the determination of numbers of aerobic organisms, developing at 10°C. and 28°C. upon a sodium caseinate medium, known to be favorable for a mixed soil flora. Urea fermenters, iron precipitating bacteria, and fungi were also detected and counted upon plates of suitable media. Dilution methods were used for anaerobes (in general), proteolytic organisms, cellulose decomposers, starch hydrolizers, aerobic and anaerobic nitrogen fixers, nitrifiers, denitrifiers, sulphur and thiosulphate oxidizers, and algae.

RESULTS

A summary of the total number of aerobic and facultative microorganisms developing on sodium caseinate agar plates is given in Table 1. Four plates of each dilution were poured and only those plates counted that contained 30 to 300 colonies. The plates incubated at 10°C. were more easily counted because of absence of molds and "spreaders" and the uniformity in size of the bacterial colonies. The counts, however, were only about one half as great as those from plates incubated at 28°C. The former

TABLE I. *Summary of aerobic plate counts in various differential media of samples taken from the mud deposits of Lake Mendota (dry basis)*

Media Demonstrating	Number of samples tested	Top Cores		
		Maximum	Minimum	Mean
		Organisms per cc.		
Iron precipitation	6	21,000	2,600	10,000
Urea fermentation	8	10,000	2,400	5,000
General aerobic flora (10° C.)	6	15,000,000	2,700,000	3,500,000
General aerobic flora (28°C.)	18	15,000,000	500,000	5,200,000
		Bottom Cores		
Iron precipitation	5	2,300	120	750
Urea fermentation	5	540	140	450
General aerobic flora (10°C.)	6	62,000	3,500	20,000
General aerobic flora (28°C.)	20	230,000	3,000	90,000

were incubated for four weeks and the latter for only two weeks. The mean average of the counts on top samples was 5,200,000 per gram dry basis and of the bottom samples 90,000 per gram. The plates, which had the general appearance of soil plates, obviously indicated a varied flora. The top samples showed in addition many red and yellow colonies, which are characteristic of the water flora. There did not appear to be a significant difference in the counts of winter and summer samples. Such uniformity is probably to be expected from the fact that conditions, particularly of temperature, are relatively unchanging in the deep deposits (Birge, Juday, and March, 1927).

Counts were also made of the summer samples on urea agar and on ferric ammonium citrate agar for organisms precipitating iron. A summary of these results is also given in Table I.

Molds were shown to be present in the top samples, as indicated by their development on acid agar plates. Duplicate plates varied greatly, however, and no accurate counts could be made, probably because of spores and the fractionation of mycelium during shaking of the samples. The molds did not form fruiting bodies on the acid agar and therefore could not be classified.

Table 2 shows the summary of dilution counts that were made on the special media. It will be noted that the samples contained in general the same types of microorganisms that are found in the soil. By far the greater numbers are in the top samples. Organisms exhibiting proteolytic activities ranged from about 1,000 per cc. in the bottom to about 1,000,000 per cc. in the top samples. Cellulose destroyers were not observed to be present in the bottom muds at all and only occasionally were detected in the top mud. From the results secured in corn mash, organisms of the types *Clostridium saccharobutyricum* and *Cl. pasteurianum* were indicated in both top and bottom samples. In one instance *Cl.*

TABLE II. *Summary of bacterial dilution counts in various differential media of samples taken from the mud deposits of Lake Mendota*

	Number of samples tested	Top Cores		
		Maximum	Minimum	Mean
		Organisms per cc.		
Anaerobes—general	13	>1,000,000	10,000	100,000
Proteolysis—liver	7	>1,000,000	10,000	1,000,000
Proteolysis—*litmus milk*	16	>1,000,000	10,000	1,000,000
Proteolysis—gelatin	16	>1,000,000	10,000	100,000
Cellulose destruction (mesophilic)	19	2	<2	<2
Cellulose destruction (thermophilic)	16	>10	<2	2
Starch hydrolysis—corn mash	19	>10,000	<10	1,000
Nitrogen fixation—aerobic	7	>10	<10	10
Nitrogen fixation—anaerobic	16	>10	<2	5
Nitrification—$NH_4^+ \rightarrow NO_2^-$	16	10	<10	3
Nitrification—$NO_2^- \rightarrow NO_3^-$	16	<10	<10	<10
Denitrification	16	>10,000	100	1,000
Thiosulphate oxidation	6	10	10	10
Sulphur oxidation	6	>10	<10	10
Algae	7	>10	>10	>10
		Bottom Cores		
Anaerobes—general	13	>10,000	<100	500
Proteolysis—liver	7	>1,000,000	100	10,000
Proteolysis—litmus milk	17	>1,000	100	500
Proteolysis—gelatin	17	>10,000	<10	1,000
Cellulose destruction (mesophilic)	20	<2	<2	<2
Cellulose destruction (thermophilic)	17	<2	<2	<2
Starch hydrolysis—corn mash	20	>1,000	<10	100
Nitrogen fixation—aerobic	6	<10	<10	<10
Nitrogen fixation—anaerobic	17	2	<2	1
Nitrification—$NH_4^+ \rightarrow NO_2^-$	17	<10	<10	<10
Nitrification—$NO_2^- \rightarrow NO_3^-$	17	<10	<10	<10
Denitrification	17	>10,000	<10	100
Thiosulphate oxidation	6	<10	<10	<10
Sulphur oxidation	6	<10	<10	<10
Algae	7	>10	<10	2

acetobutylicum was detected and isolated.

Nitrogen-fixing organisms, both aerobic (as *Azotobacter*) and anaerobic (*Cl. pasteurianum*) were detected in top samples and occasionally in bottom samples, tested in nitrogen-free media. Denitrifying organisms were found to be present in rather high dilutions of the samples and were apparently quite active therein. In no instance was active nitrification obtained, and, in fact, nitrifiers were detected only a few times in enrichment cultures from the top samples. Nitrification is known to occur in the lake water but conditions in the mud are obviously not such as to favor it. Organisms capable of oxidizing sulphur and thiosulphates were demonstrated in the top muds. Algae also were found in these. The following green and blue green types were identified microscopically; *Chroococcus* (*dispersus?*), *Microcystis* sp., *Gloeothece linearis*, *Anabaena spiroides*, *Gloeotrichia*

echinulata, *Chlorobotrys regularis*, *Scenedesmus quadricauda*, and *Scenedesmus bijuga*.

Four samples of mud, representing top and bottom cores from two locations were sent to the United States National Museum and there examined by Dr. Paul S. Conger. Some 59 species of fresh-water diatoms were found. Those listed by Dr. Conger as very common in occurrence are as follows;

	Station I	Station II
Top cores	*Stephanodiscus Niagarae* Ehr.	*Steph. Niagarae*
	Melosira granulata (Ehr.) Ralfs	*Cyclotella comta* (Ehr.) Ktz.
	Melosira crenulata (Ehr.) Ktz.	*Tabellaria fenestrata* Ktz.
	Tabellaria fenestrata Ktz.	
Bottom cores	*Steph. Nigarae* (90 per cent)	*Steph. Niagarae*
	Cyclo. comta	*Cyclo. bodanica* Eulens

DISCUSSION

It is recognized that the present survey of microorganisms in the lake mud is not at all exhaustive. It is certainly probable that many forms have escaped notice altogether. Further, the samples were limited to two stations in deep water and therefore represent only a certain type of lake bottom deposit. Similar studies should be made of other parts of the lake to get a true cross section of the microflora.

It is recognized also that the differential media and methods used in soil bacteriology are far from infallible in determining the numbers or even the presence of various groups of microorganisms, alike in soil or lake mud. Thus certain groups, particularly of anaerobes, may not appear in the higher dilutions or at all, even though present in considerable numbers. The activity of certain groups of microorganisms found in the muds is also debatable; especially is this true of the surface muds. Many forms may be active in the overlying water and be only incidental in the muds, since they may be carried down by particles in sedimentation. The surprising number and variety of aerobic organisms also deserves comment. Free oxygen in the water immediately above the mud is limited, during the greater part of the year (Birge and Juday, 1911). Certainly with the microbial population, indicated in the present survey, it must be at a premium at all times in the mud itself. It is difficult then to understand how some of the organisms, apparently there in great numbers, find it possible to live and grow.

SUMMARY

1. The samples, 43 in all, were taken from two stations in the deep water of Lake Mendota in both winter and summer. Surface and deep muds were represented.

2. A varied flora was found, including most of the known groups of soil microorganisms. Only minor differences in numbers and kinds were noted in samples taken in winter and summer from the two stations.

3. Dilution and plate counts were much higher in case of the top muds than in the bottom muds.

4. The finding of large numbers and varied types of bacteria especially in the top mud, provides the possibility and indicates the probability of various biological processes going on in the deposit.

5. Two groups of bacteria in particular were conspicuous by their absence or relative scarcity, the nitrifiers and cellulose decomposers. This peculiarity of flora should be confirmed and explained by further work.

6. A large number of fresh water diatoms were found in the muds.

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PRELIMINARY REMARKS ON THE DEEP-SEA BOTTOM SAMPLES COLLECTED IN THE PACIFIC ON THE LAST CRUISE OF THE CARNEGIE

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Seventy-five samples of the deep-sea deposits of the Southeastern and the North Pacific were collected on Cruise VII of the CARNEGIE. Although the number of these samples is relatively small, they were collected from a very large area and, therefore, afford an opportunity to reexamine many problems of deep-sea sedimentation in the light of modern methods of sedimentational and soil analysis. The questions which must be considered in such a study are (1) the determination of the various constituents of the samples with the view of ascertaining their physical and chemical nature, origin, and history before and after deposition, and (2) the classification of the samples from the point of view of the causes of the variation in bottom deposits with depth and location. In so far as these questions are answered, they may contribute to the solution of such larger problems as the time rate of deposition in the deep sea, the geologic history of the ocean basins, and the nature of the changes which the continental masses have undergone by reason of their continuing contributions to the sea and the sea floor.

A complete report on the results of several methods of investigation of these samples will be given in a forthcoming publication of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The following notes indicate some of the kinds of data which have been obtained.

Gross chemical analyses of 42 samples have been made. On the basis of their chemical composition, the majority of the samples analyzed may be classified in three groups: (1) a group of five volcanic muds and siliceous oozes from the Northwest Pacific off the coast of Japan which, although they differ widely in physical composition, are remarkably alike chemically, containing about 60.5 per cent SiO_2, and having silica-sesquioxide ratio near 6.0; (2) nine red clays from the Northeast Pacific, almost identical in chemical composition and in other ways, containing approximately 54.5 per cent SiO_2, and having silica-sesquioxide ratios near 4.0. An interesting feature of these red clays is their relatively high content of ZrO_2, in some cases as much as 0.2 per cent; (3) the third group consists of 17 globigerina oozes from the Southeast Pacific, the non-calcareous portions of some of which are high in iron, alumina, and manganese, and low in silica.

Of the remaining 11 samples, analyzed, three are red clays from the Southeast Pacific, three are terrigenous deposits collected near the coasts of North, Central, and South America; three are globigerina oozes from the central Pacific; and the remaining two samples are radiolarian oozes from the central Pacific.

In an endeavor to calculate the modal composition of the two groups of red clay and globigerina ooze, analyses of volcanic fragments, foraminiferal tests and colloidal fractions from several of the samples have been made. The foraminifera contain less than 0.5 per cent $MgCO_3$, an amount much smaller than that found by Clarke and Wheeler[1] in certain species of pelagic foraminifera. The colloidal fractions, namely, the particles less than one micron in diameter, are more basic than the whole samples. Those from the North Pacific red clays contain about 45 per cent SiO_2, and have silica-sesquioxide ratios of 2.5; while the colloidal fractions of some of the South Pacific globigerina oozes, aside from their carbonate content, are almost lateritic in composition. The base exchange capacity of the colloidal fractions was determined by Professor W. P. Kelley and was found to be similar in amount to that of soil colloids. For the red clays of the North Pacific, the base-exchange capacity is roughly 55 milli-equivalents per 100 grams, and the chief replaceable base is apparently magnesium instead of sodium.

[1] Clarke, Frank Wigglesworth, and Walter Calhoun Wheeler, The inorganic constituents of marine invertebrates. U. S. Geol. Surv., Prof. Paper 124, pp. 1–62, 1922.

Mechanical analyses by the pipette method of several red clays show that they are very fine-grained, having an average diameter of less than one micron. They are similar in their degree of sorting to other fine-grained marine sediments, such as those described by Rubey,[2] Stetson,[3] Trask,[4] and others. The globigerina oozes are more complex in mechanical composition. Their frequency curves often exhibit two maxima; one in the sand grades corresponding to the presence of tests of foraminifera, and one in the clay grades representing finely divided $CaCO_3$, also noncalcareous material. Determinations of the amount of $CaCO_3$ in the various size grades of some of these samples show that where there are two maxima in the size frequency distribution the curve for $CaCO_3$ also exhibits two maxima in the same grades.

X-ray powder diagrams of the colloidal fractions of the North Pacific red clays give patterns which are very similar to those obtained from soil colloids, and this similarity is confirmed by microscopic examination of the fine materials. Although the clay minerals which make up the larger part of these red clays have not been positively identified, they seem to be partly kaolinite and partly minerals having higher silica-sesqui-

[2] Rubey, William W., Lithologic studies of fine-grained upper Cretaceous sedimentary rocks of the Black Hills region, U. S. Geol. Surv. Prof. Paper 165, pp. 1–55, 1930.

[3] Stetson, Henry C., Scientific results of the NAUTILUS Expedition, 1931, Part 5, The bottom deposits, pp. 17–37, Papers in Physical Oceanography and Meteorology, Cambridge, Mass., 1933.

[4] Trask, Parker D., Origin and environment of source sediments of petroleum, Gulf Publ. Company, Houston, pp. 307, 1932.

oxide ratios, such as montmorillonite. All of the samples yield diffraction lines which are identical with those give by quartz. Whether this quartz is authigenic or detrital has not been determined. The fine fractions of the globigerina oozes show very strong calcite lines and give no indication of the presence of aragonite, although if any of the calcium carbonate is inorganically precipitated, as suggested by Heim,[5] it might be expected to be in the form of aragonite. An interesting result of the X-ray analysis has been the definite confirmation of Renard's[6] and Lee's[7] identification of phillipsite in the deposits of the South Pacific.

Many other types of investigation have been carried out on these samples The writer has examined microscopically and described in detail the sand grades of the mechanically analyzed samples, and has attempted to identify the constituents of the silt and clay grades. Dr. J. A. Cushman has identified the foraminifera submitted to him from sixteen of the samples; and other experts have examined the remains of sponges, echinoids, Bryozoa, and ostracodes which have been separated from the samples. Mr. George Steiger has made spectroscopic examinations for boron, barium, beryllium, bismuth, germanium, tin, and zinc; and Dr. P. G. Nutting has made a study of the mean grain densities, thermal dehydration relationships and vapor pressures of some of the red clays and globigerina oozes. Dr. Parker D. Trask[4] has measured the contents of organic matter on 39, and Dr. C. S. Piggott[8] has determined the radium content of 27 of the samples. The results of the last two workers have already been published.

[5] Heim, A., Über submarine Denudation und chemische Sedimente, Geol. Rundschau, Bd. 15, pp. 1–47, 1924.

[6] Murray, John, and A. F. Renard, Deep-sea deposits, CHALLENGER Exped., London, 1891.

[7] Murray, J., and G. V. Lee, The depth and marine deposits of the Pacific, Mem. Mus. Comp. Zoology, vol. 38, no. 1, pp. 1–169, 1909.

[8] Piggot, C. S., Radium content of ocean-bottom sediments. Am. Jour. Sci, 5th ser., vol. 25, pp. 229–238, 1933.

JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 5, NO. 1, PP. 40–51, FIGS. 1–2, TABLES I–III, APRIL, 1935

MARINE EROSION OF GLACIAL DEPOSITS IN MASSACHUSETTS BAY

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ABSTRACT

In Massachusetts Bay there is a belt of subangular pebbles roughly paralleling the shore which is a lag concentrate formed by the washing out of the finer constituents of fluvio-glacial deposits. Although in shallow water, and exposed to the full force of easterly gales, this bottom is relatively undisturbed, as the pebbles are still angular to subangular, and some of them covered with red, calcareous algae. Bottom topography is irregular as the result of glacial deposition. Although working on unconsolidated deposits, the sea has not been able to smooth out these irregularities and develop a well-graded profile.

Trowbridge and Shepard, in their article "Sedimentation in Massachusetts Bay,"[1] comment on a zone which they term "rocky bottom" that appears to run parallel to both the north and south shores of the bay. According to their chart (Plate 2) it is usually separated from the mainland by a belt of sand of varying width. Seaward of this rocky area they have plotted "sand and gravel." They obtained no samples from the rocky zone and were therefore unable to tell whether it consisted of bed rock or of large rock fragments. They suggest (1) that the continental ice sheet may have scraped away the finer material down to bedrock, or (2) that it was washed away at a time of lowered sea level. A feature of this sort is sufficiently unusual to warrant further investigation. The present authors accordingly undertook a rather detailed sampling of the region off the south shore, where the feature is best developed, supplemented by a few samples off the north shore. The data obtained demonstrate that the zone is not bedrock. It also deserves brief discussion because of rather peculiar sedimentary relationships.

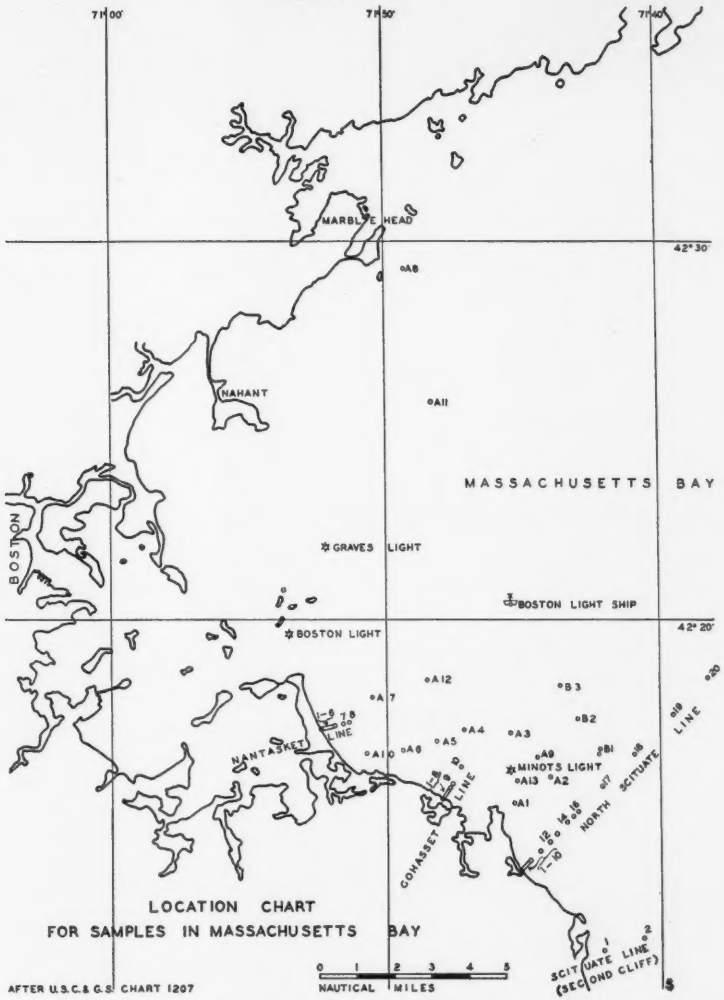
The dredge used consisted of a section of 4-inch iron pipe a foot long. The towing line was attached by a heavy wire bail. The "cod end" was a 2 foot length of inner tube stretched over one end of the pipe. This dredge was found to be very effective on all types of bottom and the rubber more resistant to wear than the customary canvas. Also, when the end of the inner tube was untied for removing the sample, the rubber could be washed free of fine material much more easily than is possible with canvas. To give a low angle of drag, a 10-pound lead was attached to the line ten feet ahead of the dredge.

The rocky area, or zone of subangular pebbles, as we shall call it,

[1] Trowbridge, H. C., and Shepard, F. P., Sedimentation in Massachusetts Bay: *Jour. Sedimentary Petrology*. vol. 2, pp. 3–37, 1932.

was encountered in four places by traverses starting close to the shore and running seaward. From south to north they are: Second Cliff, Scituate; North Scituate Beach; Sandy Beach, Cohasset; and Nantasket. Individual samples were taken from the sub-angular pebble zone and from positions next to seaward which are not part of any definite traverse.

FIGURE 1



MECHANICAL ANALYSIS

The important textural features of the samples are presented as computed by Trask's method.[2] For those unacquainted with this method of presentation of data the following brief description will be of some assistance. Mechanical analysis of each sample was made by the combined sieve and hydrometer method, developed by Dr. A. Casagrande of the Harvard Engineering School, which eliminates the principle errors formerly existing in hydrometer technique. The data obtained are plotted as a cumulative curve, usually on four cycle semilogarithmic graph paper. From this curve the first quartile, median, and third quartile diameters are read. To aid in the comparison of a number of samples, in addition to the median, which is probably the one most important textural characteristic of a given sediment, an expression for sorting and one for skewness is used.

The coefficient of sorting is obtained by substitution in the formula $So = \sqrt{\frac{Q1}{Q3}}$. Thus perfect sorting equals unity. The experience of the present authors with many samples has given an average value of 1.25 for beach sands, and of 1.45 for well sorted near shore sediments.

The coefficient of skewness is derived from the formula $Sk = \frac{Q1 \times Q3}{M^2}$. It indicates on which side of the median diameter, and how far from it, the mode, or peak of size distribution lies. For ease of interpretation, i.e., to show readily on which side of the median the mode lies and its relative divergence, the logarithm of the skewness is given. Thus a log of 0.0 ($Sk = 1$) indicates a symetrical size distribution curve, the mode coinciding with the median; a plus log (Sk greater than 1) that the mode is on the fine side of the median; a minus log the opposite.

Table I gives the statistical constants described above. Table II lists each sample split into arbitrary size divisions which are also read from the same cumulative curves.

DESCRIPTION OF AREA

The North Scituate, Cohasset and Nantasket lines all begin at high water mark and cross the sandy zone near shore. From the statistical constants we find it is a uniform, fine-grained sand with the median diameters falling between 0.1 and 0.2 mm. except on the beach. The sorting is good and the skewness close to zero, the latter indicating that the curves are symmetrical and the mode close to the median. Progressing seaward we encounter an abrupt change in texture which is reflected in a large increase in the median diameter and in the percentages of the coarser grades. This marks the contact between the sand and the subangular pebble zone. Every time this contact has been crossed, i.e. Scituate, North Scituate, on the Nantasket line, and at two positions inshore from sample A-7, the same sharp transition has been found. The only exception noted

[2] Trask, P. D., Origin and environment of source sediments of petroleum, Houston, 1932.

TABLE I

Sample	Depth in feet at mean low water	Statistical constants (in millimeters)				Log Sk
		Q1	*M*	*Q3*	*S0*	
Scituate Line						
1	45	0.177	0.126	0.075	1.54	−.08
2	60	39.0	33.2	29.0	1.16	.01
North Scituate Line						
1 high tide		4.3	2.28	1.74	1.57	.16
2 low tide		.870	.315	.190	2.14	.22
3	3	.192	.174	.155	1.11	−.01
4	4	.210	.180	.155	1.16	.00
5	6	.192	.174	.155	1.11	−.01
6	10	.182	.160	.140	1.14	.00
7	12	.174	.145	.120	1.20	.00
8	14	.184	.162	.141	1.14	.00
9	15	.162	.138	.115	1.19	−.01
10	15	.154	.138	.121	1.13	−.01
11	16	.158	.138	.120	1.15	.00
12	40	.155	.138	.120	1.14	−.01
13 hung	76					
14	80	47.0	43.0	39.0	1.10	.00
15 hung	70					
16	50	48.0	44.0	40.0	1.10	.00
17	60	38.0	14.8	5.65	2.59	−.01
18	95	26.0	10.8	3.25	2.83	−.14
19	130	12.3	8.4	3.95	1.76	−.16
20	170	.034	.017	.003	3.12	−.39
Cohasset Line						
1 high tide		.220	.190	.165	1.15	.00
2 mid-tide		.240	.200	.175	1.17	.02
3 low tide		.725	.315	.193	1.94	.15
4	4	.230	.180	.155	1.22	.04
5	10	.215	.170	.140	1.24	.02
6	13	42.0	32.5	22.2	1.38	−.05
7	15	31.8	28.1	22.8	1.18	−.04
8	20	44.6	39.2	25.8	1.31	−.12
9	20	42.0	34.8	29.7	1.19	.01
10	40	30.4	26.5	21.0	1.20	−.04
Nantasket Line						
1 high tide		.230	.200	.175	1.15	.00
2 mid-tide		.240	.182	.155	1.24	.05
3 low tide		.250	.170	.142	1.33	.09
4	8	.180	.150	.130	1.18	.02
5	11	.210	.178	.145	1.20	−.02
6	15	.150	.132	.115	1.14	.00
7	25	60.0	55.0	34.2	1.32	−.17
8	35	41.8	29.8	18.3	1.51	−.06
Miscellaneous Samples in Sub-angular Pebble Zone						
A1	35	41.0	29.7	13.5	1.74	−.20
A2	50	42.5	35.8	29.2	1.21	−.01
A3	70	59.0	55.0	48.0	1.11	−.03
A4	60	45.5	41.0	36.8	1.11	.00
A5	45	44.0	38.0	28.0	1.25	−.07
A6	35	56.3	43.8	30.5	1.36	−.05
A7	45	39.0	30.0	22.0	1.33	−.02

TABLE I (*Continued*)

Sample	Depth in feet at mean low water	Statistical constants (in millimeters)				Log *Sk*
		Q1	*M*	*Q3*	*S0*	
A8	50	30.0	25.2	16.3	1.36	−.11
A9	90	29.3	11.2	3.02	3.12	−.15
A10	45	29.7	15.5	.8	6.03	−1.01
A11	95	.318	.250	.200	1.26	.01
A12	70	.178	.145	.116	1.24	−.01
A13	60	.170	.109	.075	1.50	.03
Samples Outside Subangular Pebble Zone						
B1	70	54.0	46.0	39.0	1.18	.00
B2	100	39.4	28.8	8.0	2.22	−.42
B3	110	.246	.186	.157	1.25	.05

TABLE II. *Size fractions*
(Based on percentages of total weight)

Sample	30–100 mm.	Gravel 1–30 mm.	Sand 0.05–1 mm.	Silt 0.005–.05 mm.	Clay 0.001–005 mm.	Colloid 0–.001 mm.
Scituate Line						
1	0	0	84.0	13.0	3.0	0
2	70.0	30.0	0	0	0	0
North Scituate Line						
1	0	97.7	2.3	0	0	0
2	0	20.5	79.5	0	0	0
3	0	0	100.0	0	0	0
4	0	0	100.0	0	0	0
5	0	0	100.0	0	0	0
6	0	0	100.0	0	0	0
7	0	0	100.0	0	0	0
8	0	0	100.0	0	0	0
9	0	0	99.7	.3	0	0
10	0	0	99.0	1.0	0	0
11	0	0	99.0	1.0	0	0
12	0	.1	98.5	1.4	0	0
13 hung						
14	95.0	5.0	0	0	0	0
15 hung						
16	85.5	14.4	.1	0	0	0
17	37.0	59.5	1.7	1.8	0	0
18	23.5	70.5	5.0	1.0	0	0
19	3.0	87.0	6.0	4.0	0	0
20	0	0	13.8	58.2	14.2	13.8
Cohasset Line						
1	0	0	100.0	0	0	0
2	0	3.2	96.8	0	0	0
3	0	18.0	82.0	0	0	0
4	0	3.0	97.0	0	0	0
5	0	0	100.0	0	0	0
6	56.0	41.0	3.0	0	0	0
7	36.0	60.0	4.0	0	0	0
8	70.0	24.0	6.0	0	0	0
9	74.0	26.0	0	0	0	0
10	27.0	72.9	.1	0	0	0

TABLE II (*Continued*)

Sample	30–100 mm.	Gravel 1–30 mm.	Sand 0.05–1 mm.	Silt 0.005–05 mm.	Clay 0.001–005 mm.	Colloid 0–.001 mm.
Nantasket Line						
1	0	0	100.0	0	0	0
2	0	3.5	96.5	0	0	0
3	0	12.5	87.5	0	0	0
4	0	6.0	94.0	0	0	0
5	0	0	100.0	0	0	0
6	0	0	100.0	0	0	0
7	96.0	4.0	4.0	0	0	0
8	49.7	48.8	1.5	0	0	0
Miscellaneous Samples in Subangular Pebble Zone						
A1	49.5	48.5	2.0	0	0	0
A2	72.0	27.7	.3	0	0	0
A3	99.0	1.0	0	0	0	0
A4	89.0	10.8	.2	0	0	0
A5	70.0	29.9	.1	0	0	0
A6	76.0	23.9	.1	0	0	0
A7	50.0	49.9	.1	0	0	0
A8	24.5	75.0	.5	0	0	0
A9	23.0	67.0	10.0	0	0	0
A10	23.0	49.5	27.3	0.2	0	0
A11	0	.8	99.2	0	0	0
A12	0	0	89.5	8.0	2.0	.5
A13	0	0	90.0	9.0	1.0	0
Samples Outside Subangular Pebble Zone						
B1	80.5	16.5	3.0	0	0	0
B2	48.0	36.5	15.5	0	0	0
B3	0	7.5	92.5	0	0	0

was sample A-10. Here we may well have scraped close to or across the actual contact.

Samples A-1 to A-13 are from various parts of the subangular pebble zone and were taken to complement the data obtained from the traverses. The same characteristics are manifest wherever this zone is sampled. It is apparent from the values in the above tables that we are not dealing with a zone of clean-washed bedrock, but with a pebble bottom. A little sand is present, but the proportion of the coarse material is so large that it completely dominates the sample. In most cases the sorting is good to fair. At first glance one might consider the sorting an artificial one, due to the fact that the dredge could only take pebbles up to four inches (approximately 100 mm.) in their shortest dimension. An examination of the samples shows that this factor has little effect. Only two samples had pebbles (85 and 89 mm.) which approached the dredge limit; all the other samples had relatively smaller material. We may, therefore, assume that there are comparatively few large pebbles present. Hence in most cases we are dealing with a fluvio-

glacial deposit and not with till. This preliminary sorting has since been improved by elutriation of the finer material, under present day marine conditions, leaving a coarse concentrate.

The subangular pebble zone is by no means the uniform, continuous feature shown by Trowbridge and Shepard as "rocky" on their plate 2. A glance at the pilot chart will show how irregular are the soundings. As might be expected there is a relationship between the texture of the sediments and the depth of the water. Samples from protected areas contain more fine material than usual. A-12 is in a depression below the general level of the sea floor. A-13 is likewise protected by shallower bottom to seaward. An accurate sediment map would break up this region, but this is a detail which does not particularly affect the main problem.

We have emphasized the fact that in the majority of cases the zone under discussion is not bedrock but loose material. However, an occasional outcrop is to be expected, considering the nature of the country with which we are dealing. On the south shore of the bay the granite of the mainland gradually slopes seaward. Small nobs projecting above the main mass form ledges, dry at high water, which make offshore for more than a mile. Beyond them are others which emerge only at low water. It is reasonable to suppose that there are still more which never emerge at all and are nearly flush with the general surface of the bottom. Similar conditions are found on the north shore. To the man operating the drag dredge it is an easy matter to tell by the feel of the line whether he is on "rocky" bottom, but when the dredge hangs up, or skates along the bottom without taking a sample, it is impossible for him to tell whether he is dealing with bedrock or large boulders. Places where the dredge hung have been noted in the tables; except for these it rarely failed to take a sample.

Outside the subangular pebble zone, which has just been described, Trowbridge and Shepard show a broad continuous belt which they call "sand and gravel." On the North Scituate line between samples 16 and 17 we reach this area. The median diameter drops, the percentage of the gravel size shows a marked increase at the expense of the larger sizes, the sorting becomes poorer and the curve more unsymmetrical. Samples 18 and 19 show similar tendencies. Other samples, B-1 to B-3 were taken in this same zone. Of these, B-1 and B-2 resemble the outer end of the North Scituate line. In samples from this zone in which the texture is still dominated by the coarser grades, the sorting is worse than in the subangular pebble zone. This is due to the presence of a larger percentage of finer material. B-3 and A-11 are essentially sands, although A-11 contains a large pebble which was not included in the calculations as there are no transitional sizes. Taken as a whole this outer region runs much higher in the finer grades than does the subangular pebble zone.

The end of the North Scituate

line, sample 20, lies in the zone of silt and clay which occupies the deeper parts of the bay.

CHARACTERISTICS OF THE PEBBLES

The individual pebbles from the region in question are mostly angular to subangular of the type commonly found in the fluvio-glacial deposits around the shores of the bay. The contrast between these pebbles and the ones from the beaches in the vicinity is very marked. (Figure 2). The latter exhibit a high degree of rounding due to the exposed position of the coast, and the consequent pounding received during easterly gales. It is obvious that the offshore pebbles have never been on any beach and that they are being little abraded in their present position. As a further illustration of this point, many of the larger pebbles, from samples taken last October, carry thick growths of red, calcareous algae, and in some cases, bryozoans and calcareous worm tubes. One face of each pebble was generally bare, and thus the growth appears to be confined to the sides exposed to the water. This would indicate that the pebbles are rarely turned over. The algae on the pebbles taken this spring did not appear as fresh and as well developed as on those taken from the same localities last fall. The fronds looked somewhat abraded, and it is probable that this occurred during the severe winter gales when the finer constituents were in motion. The small pebbles are bare as seen from Figure 2. A limy coating of this sort could be easily removed, and, that most of it remained, coupled with the fact that even the smaller pebbles retained their subangular shapes, is a good indication that the sea is not competent to modify the bottom profile at these depths to any great extent.

MOVEMENT OF BOTTOM MATERIAL

The results obtained off Cohasset with the pans devised to catch sediments shifting over the bottom[3] have an important bearing on the origin of the zone of pebble bottom. The median diameters given in Table I show how marked is the contact between the sand and the pebbles. Any data on the interchange of sediment between the two would be useful in interpreting the zone of "hard" bottom. Accordingly the contact was located and one pan placed on the sand in 24 feet of water and another on pebbles in 30 feet of water, about 400 yards out from the first. The positions were slightly protected by outlying ledges. The pans were on the bottom from November 11 to December 16, 1933, and the stations visited November 18, December 2 and 16. On the first two dates the pan on the pebble bottom contained practically no sand—only 0.35 and 0.38 grams respectively, none of the grains ranging much above .147 mm. The material below 0.074 totalled 3.86 and 1.33 grams. During the same period the sand bottom pan collected 469.36 grams of sand and 3.31 grams of material below .074 mm. to November 18, and 920.58

[3] Raymond P. E., and Stetson, H. C., *Science*, vol. 73, No. 1882, pp. 105–106, Jan. 23, 1931.

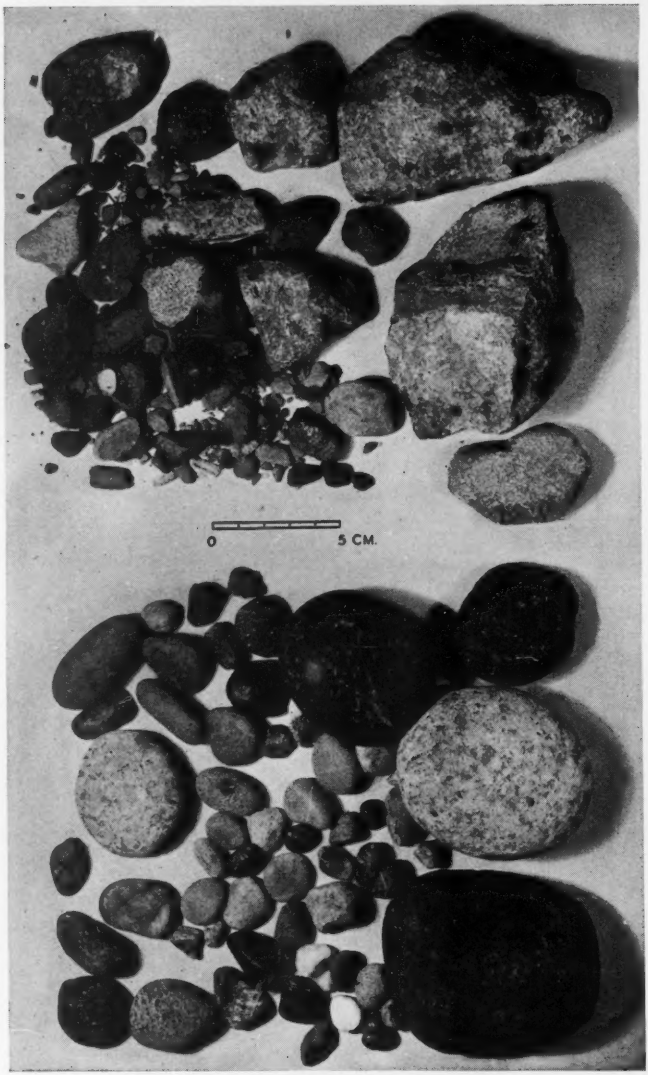


FIG. 2. Bottom sample A-6, above, from the sub-angular pebble zone with red algae covering the larger fragments. Below, pebbles from a beach at Cohasset.

grams of sand and 9.88 grams of finer material to December 2. The largest grains collected remained on the 0.417 sieve but constituted only 0.2 per cent of the sample in each case. The period from November 11 to December 2 passed with no gales from the eastward which produce the heaviest seas on this coast. The increase of sand on December 2 over November 18 is accounted for by several hard northwesters, which, though in the main an offshore wind, can produce a heavy chop on the south shore of the bay. These short, steep waves however, were not capable of transporting the sand into the pebble area to any appreciable extent. During the interval December 2 to 16 there occurred a heavy easterly gale. The sand bottom pan was completely filled (more than 10 kg.) and partly buried, while the offshore pan caught 1048 grams. In addition to the sand from inshore, the pebble bottom itself was stirred up, as the range in size of particles caught rises as high as 9.3 mm. None of the coarse material moved into the sand bottom pan unless attached to kelp stalks. The inshore pan was sampled in three sections. Table III gives the details of the mechanical analysis.

SUMMARY

From the above evidence it seems probable that the continental ice sheet and not the sea is largely responsible for the configuration of the near-shore bottom as we find it in Massachusetts Bay. The soundings are very irregular and the topography as well as the type of sediment point to a glacial origin.

Since the close of the glacial period the sea has modified the bottom but

TABLE III. *Data from Sediment Traps off Cahasset.*

	Statistical Constants (in millimeters)				Log *Sk*
	*Q*1	*M*	*Q*3	*S*0	
1 Sand bottom, Nov. 11–18	.174	.139	.114	1.23	.01
2 Sand bottom, Nov. 18–Dec. 2	.175	.141	.118	1.22	.02
3 Sand bottom, Dec. 2–16; top section	.208	.172	.141	1.21	.00
4 Sand bottom, Dec. 2–16; middle section	.357	.178	.132	1.65	.17
5 Sand bottom, Dec. 2–16; bottom section	.510	.202	.145	1.87	.26
6 Pebble bottom, Dec. 2–16	3.50	1.98	1.10	1.78	−.01

	Size Fractions Based on Percentage of Total Weight			
	Gravel 1–30 mm.	Sand .05–1	Silt .005–.05	Clay .001–.005
1 Sand bottom Nov. 11–18		99.6	.4	
2 Sand bottom, Nov. 18–Dec. 2		99.5	.4	.1
3 Sand bottom, Dec. 2–16; top section	4.0	95.8	.2	
4 Sand bottom, Dec. 2–16; middle section	6.0	93.5	.5	.
5 Sand bottom, Dec. 2–16; bottom section	5.0	95.0		
6 Pebble bottom Dec. 2–16	77.7	21.0	1.0	3.

little, as subangular pebbles are found, often covered with algae, in relatively shallow water. At the same time it was observed that during periods of severe weather the inshore sand is carried out into the pebble zone in considerable quantities. Under these conditions the smaller constituents of the outer zone are likewise put into suspension, but apparently none are carried inwards. The surface of this zone, therefore, appears to be a lag concentrate. Whichever way the sand drifts, the zone of subangular pebbles remains a region of scour in which the fine grade sizes can not long remain. They must either go seaward or return to the beach. Samples B-1 to B-3 taken outside the sub-angular pebble zone contain more sand than is usual within the zone. The large, subangular pebbles are still present, however, so deposition must be very slow. Near the lightship several algae covered pebbles were found indicating lack of deposition in this area as well. Due to glacial interference, the present bottom is above the profile of equilibrium, and the sea is powerless to deepen this part of the foreshore further due to the nature of the materials encountered. It is rather surprising that a relatively undisturbed bottom, in which the largest pebbles rarely exceed 150 to 200 grams, is encountered in such shallow water, particularly as the coast is a very exposed one and receives the full force of easterly gales.

Such a condition, which really acts as a natural rip-rap, must be a factor in checking the speed of erosion, as waves which can not deepen the foreshore to full wave base, are prevented from expending their full energy in the erosion of the coastline.

In a discussion of Trowbridge and Shepard's paper, Hough[4] comments on a lag concentrate formed by the washing out of till on the bottom of Lake Michigan. However, the veneer of pebbles was sufficiently thin to enable him to obtain clay below it in some cases.

If a relative change of sea level were to elevate the region off the south shore a hundred feet or more, we would have an area which, except for absence of wind abrasion marks, could be compared with a sort of desert pavement. Small dunes would border the present shoreline; the uneven surface of clean washed pebbles would be broken up by depressions filled with fine sand, and a few granite nobs would rise above the general surface. The protection offered the underlying fluvioglacial material would make erosion very slow under ordinary conditions of subaerial erosion. The true origin of such a terrain would be very difficult to explain.

The sharp contact between the sand and the subangular pebble zone can be interpreted only in a very general way. That a clearly defined boundary of this sort can be maintained over so large an area is not fortuitous. Perhaps it indicates a critical point in the action of waves generated currents on the bottom, such as must occur when a purely

[4] Hough, J. L., Discussion, *Jour. Sedimentary Petrology*, vol. 2, no. 2, p. 131, 1932.

oscillatory wave changes into a wave of translation. Perhaps differences in exposure to the full sweep of storm waves, due to irregularities of the bottom, account for the varying depths at which it is found, although in the case of Nantasket it is difficult to see any such difference between the two ends of the beach. At the northerly end the contact lies in about forty feet of water; at the southerly in twenty feet or less. All of these beaches, including Nantasket whose drumlins are now artificially protected, have at present no visible source of sand supply. It is evident, therefore, that wave action tends for the most part to maintain beaches of this sort which are bounded by rocky headlands. At times, sand is being slowly subtracted, as has been noted from the catches of the sediment traps, and from the composition of the sand and gravel zone that lies off the relatively clean washed pebbles (B-1 to B-3, North Scituate 17 to 19), but this action must be very slow. Eventually the sand will probably be removed and we shall have a lag concentrate over all the shallow water bottoms of the bay.

REVIEWS

HAND, I. P., *The Character and magnitude of the dense dust cloud which passed over Washington, D. C., May 11, 1934.* Monthly Weather Review, vol. 62, no. 5, 1934, pp. 156–157.

The dust cloud of May, 1934, seems to have been the greatest over northeastern United States since the initiation of accurate observation. Dust counts made in Washington on May 11, 1934 showed the number of particles per cubic centimeter to range from 3,150 at ten P.M. to 12,180 at three P.M. and from 903 at eight A.M. on May 12 to 4,620 at five P.M. of the same day. The maximum number, 12,180, exceeded by 72 per cent the number of any previous count. The number seems to have decreased rather rapidly southward as the maximum observed at stations in Virginia was 1,365 particles per cubic centimeter at Criglersville. The dimensions of the particles ranged from 0.9μ to 1.0μ. Mr. Hand estimates that at the time of maximum abundance of dust particles the atmosphere held 101 tons over each square mile. The area affected by the dust cloud, the deposit of dust made everywhere within the area affected, and the tremendous quantity in the atmosphere over each square mile even as far east as Washington D. C., speak eloquently for the importance of the atmosphere as an agent in sedimentation.

The dust of this cloud seems to have have been largely derived from points north of Nebraska; or from Montana, the Dakotas, Minnesota and Wisconsin. This dust was lost to the regions of derivation and deposited in part in the more humid regions of northeastern United States and in the adjacent Atlantic Ocean. That deposited on the land was probably largely washed away following the first rain of importance.

A dust cloud of this magnitude could hardly have been possible when the regions of derivation were "grass country." Such a cloud was made possible by cultivation of the "grass lands"; the occurrence recommends that much of these lands be placed under permanent vegetable cover lest they be literally blown away.

Examination of dust particles collected in Washington showed quartz and gypsum to be present in considerable quantity, calcite in small quantity, some fresh orthoclase and microcline, and minor quantities of several other minerals. The range in dimension was found to be from 0.005 to 0.04 mm. Examination made at Blue Hill, Mass., showed the most common minerals to be quartz and feldspar.

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SZÁDECZKY-KARDOSS, E. v., *Flussschotteranalyse und Abtragung-gebiet,* Mitteilungen der berg- und hüttenmännischen Abteilung an der kg. ung. Hochschule für Berg- und Forstwesen zu Sopron, Ungarn, vol. 4, pp. 1–38, 1932; vol. 5, pp. 1–23, 1933.

These two papers are in German but an English summary is given in the beginning of part 2.

Part 1 considers the behavior of fluvial gravels of great abrasive resistance under conditions of transportation for limited distances, the region of study being adjacent to the town of Kolozsvár in Hungary. The minimum distances of travel of the constituents were as follows: andesite 12.5 km., amphibolite 14 km., phyllite 15 km., gneiss 18 km., mica schist 20 km., pegmatite 22 km., granite 32 km., Permian quartzite 62 km. The diameters of the particles ranged from 1/16 mm. to 200 mm. and 1,019 cobbles, pebbles, granules and sand grains were studied. It was found that the quantity ratios and the roundness of the different rocks depend on the distance traveled and the abrasive resistance. The quotient of the distance of travel and the abrasive

resistance is termed reduced distance of travel and it was found that with small reduced distances the maximum percentage of particles is near the maximum size and with increase in distance the quantitative maximum shifts toward the medium and ultimately to the minimum sizes. The coarse and fine grain fractions gradually vanish and with very great reduced distances of travel the rocks of which they are composed disappear from the gravels. The original dimensions of the particles depend primarily upon the relief of the district from which the particles are derived.

Maximum sizes of brittle rocks, as granite, diminish in dimension with transportation with rapid increase in roundness in the beginning, whereas particles of medium dimension of 8 to 32 mm. remain angular over relatively long distances of travel. This is partly attributed to the development of secondary grains from crushing of larger particles. Particles less than 8 mm. in diameter are little broken and become only slightly rounded and the smallest grains also develop little rounding. Long reduced distances of travel result in reduction of all particles to small size. Tough rocks, as amphibolite, fracture less and the difference in roundness between coarse and fine sizes is less.

The determination of the roundness of the maximum sizes permits calculation of the ratio of reduced minimum distances of travel of different rocks. In the coarse size average values of roundness of the different rocks are proportional to their reduced distances of travel and increase with the latter. For rocks of at least 5 mm. in diameter under conditions of limited reduced distances of travel, the ratios of the areas of distribution may be calculated as the average percentages of these rocks in gravels are proportional to the areas of denudation.

Part 2 discusses gravels transported short distances, the rock particles studied being derived from alluvial deposits of the Kis-Szamos River in Hungary near the village of Gyalu. The minimum distances of travel of the resistant rocks in the gravel were Cretaceous sandstone 0.1 km., amphibolite 1 km., phyllite 2 km., gneiss 5 km., mica schist 7 km., pegmatite 9 km., andesite 10 km., granite 19 km., and Permian quartzite 49 km. The maximum diameter of the particles was 200 mm. If was found that average quantities of rock particles under conditions of short transportation are not proportional to the areas undergoing erosion, that the quantitative proportions of rocks originating from the immediate neighborhood are greater than the respective areas of supply, and that the average roundness of the coarse sizes bears a close inverse relation to the reduced distance of travel.

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FOWLER, G. M., LYDEN, J. P., GREGORY, F. E., and AGAR, W. M., *Chertification in the Tri-State (Oklahoma, Kansas, Missouri) Mining District*, Technical Publication No. 532-I, 45, American Institute of Mining and Metallurgical Engineers, pp. 1–50, text figures 40, tables 2, 1934.

This work consists of three parts. The first, by Fowler and Lyden, deals with the stratigraphy, the relationship of the limestones and cherts of the district, the origin of the cherts, and theories respecting origin of chert. The authors state that all the cherts in the Boone formation of the Tri-State district are related to structural conditions, are of epigenetic origin and developed prior to the Chester as the latter is free from chert. The term chertification is proposed for the process by which limestone is replaced by "introduced silicic acid."

The second part of the paper by Gregory, considers the chert in detail. It is stated that two distinct varieties are found in the Tri-State district, thus agreeing with Buehler, Buckley, Laney and Weidman. The older chert is found around some centers of deformation and

above some stylolitic partings. This chert is composed of ovaloid grains of chalcedony in a matrix of quartz particles and sponge spicules. It contains pyrite, marcasite, inclusions of limestone, and a little tourmaline. The color ranges from dark brown to white. The younger chert is of abundant occurrence. Generally, it has a lighter color than the older chert, a less dense texture, and commonly contains fragments of the older chert. It also contains fewer sponge spicules. This chert grades into the porous and cellular forms known as cotton rock and tripoli.

The third part of the paper, by Agar, considers the petrology of the cherts.

The reviewer has no opinion on the origin of the cherts in the Boone formation in the Tri-State district but on general principles he hesitates to accept the generalization that all of these cherts are of epigenetic origin and related to lines of structural deformation. His experience has demonstrated that wide reaching generalizations can rarely be sustained and, again in general principles, one may expect that ultimately it will be shown that cherts of syngenetic time relations are present in this district.

The interesting occurrence of tourmaline in the older chert is given by Gregory and also by Agar, but the real importance of this mineral rests on whether it is of allothogenic or authigenic origin. The reviewer has not found that this determination has been made.

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